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BMR Bulletin
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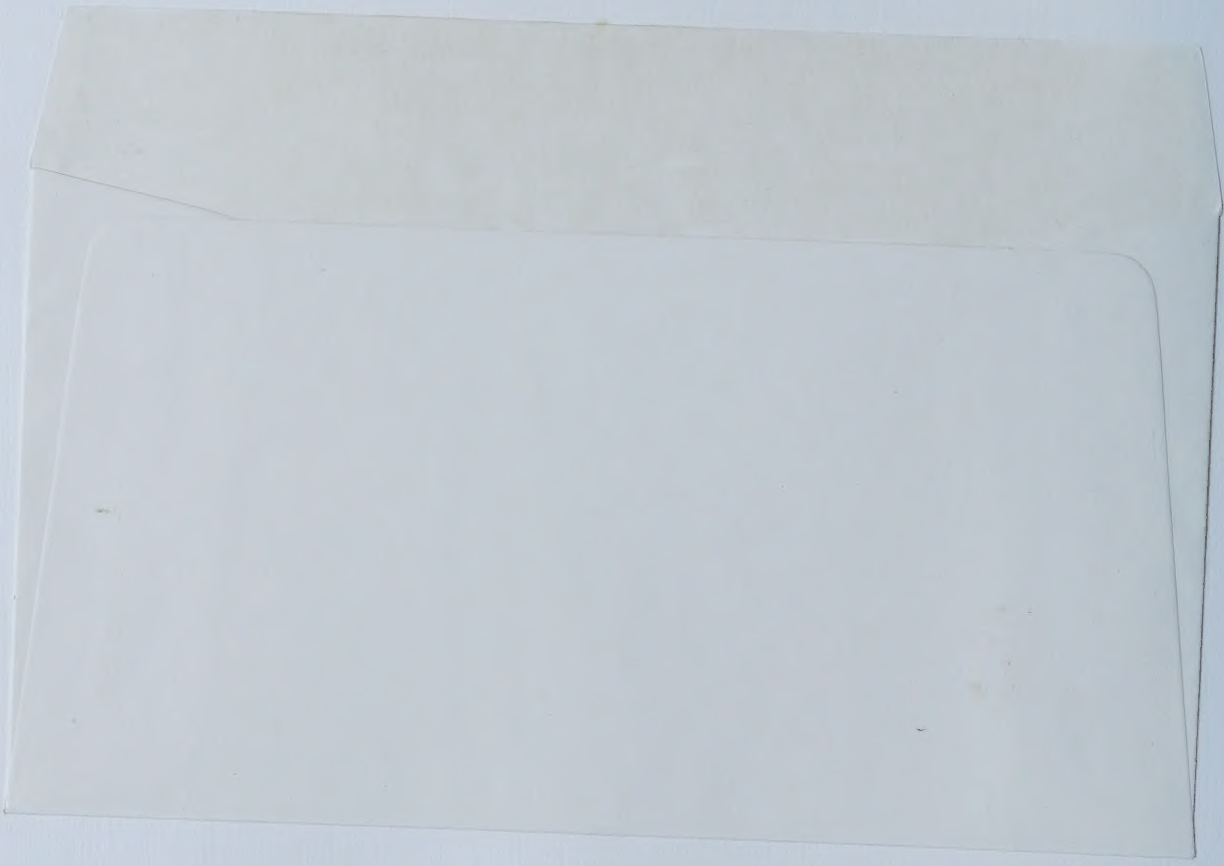
D. H. Blake, A. J. Stewart, I. P. Sweet & I. G. Hone



R BULLETIN 226
R MF222
SN 0084-7089
BN 0 644 06300 9

GEOLOGY OF THE PROTEROZOIC
DAVENPO4RT PROVINCE, CENTRAL .
AUSTRALIA By D.H.Blake & others
Bureau of Mineral Resources, Australia 1987

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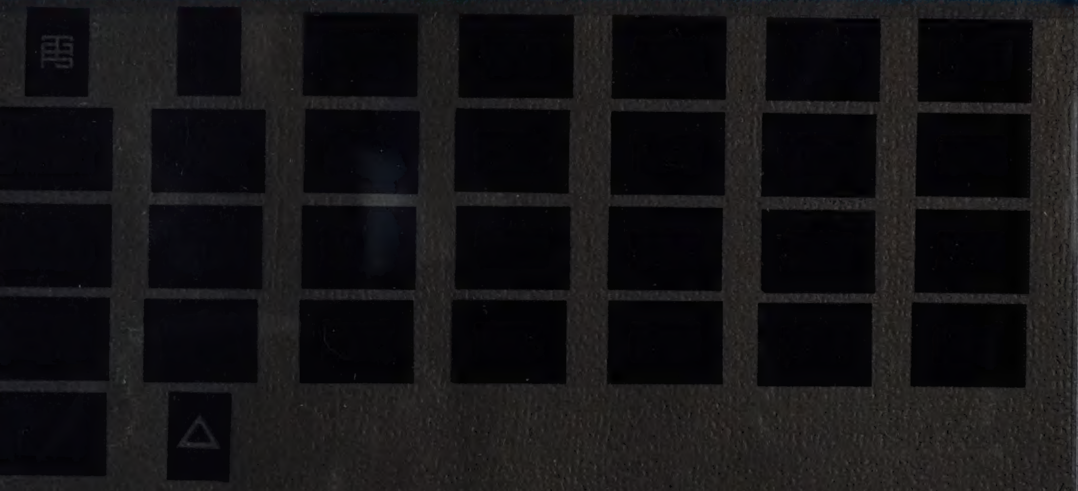

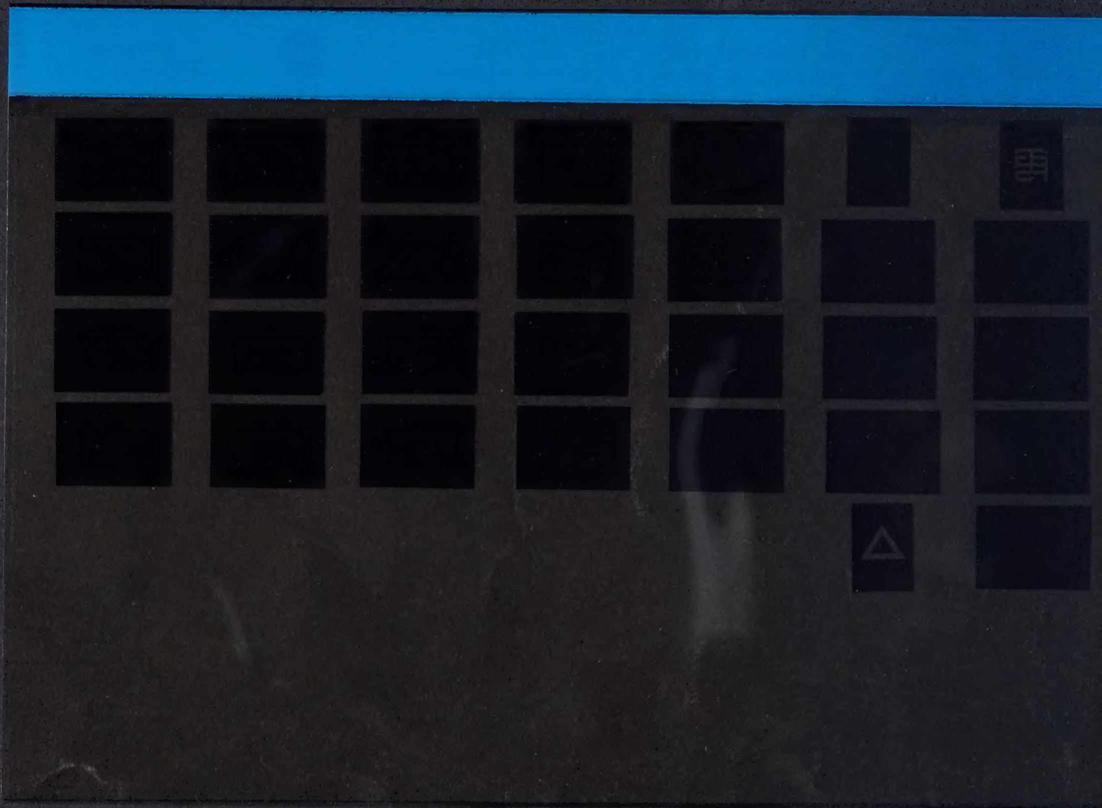

DEPARTMENT OF RESOURCES AND ENERGY
BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

BULLETIN 226

Geology of the Proterozoic Davenport province, central Australia

D. H. BLAKE, A. J. STEWART, I. P. SWEET & I. G. HONE

AUSTRALIAN GOVERNMENT PUBLISHING SERVICE
CANBERRA 1987

DEPARTMENT OF RESOURCES AND ENERGY

MINISTER: SENATOR THE HON. GARETH EVANS Q.C.

SECRETARY: G. C. EVANS

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

DIRECTOR: R. W. R. RUTLAND

Published for the Bureau of Mineral Resources, Geology and Geophysics
by the Australian Government Publishing Service

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ISBN 0 644 06300 9
ISSN 0084-7089

This Bulletin was edited by K. H. Wolf.
Line drawings by I. Hartig.

Cover: Vertical aerial photograph showing north and east-trending folds in the Hatches Creek Group in the central part of the Davenport province (northern limb of the Skinner Anticline, Wauchope Fold Belt, KURUNDI REGION). The distance across the photograph from left to right (west to east) is 12.5 km. (*Bonney Well* RC9, run 7, no. 0250, CAG 4111, 30.6.1971.)
Frontispiece. The Devils Marbles on the Stuart Highway 9 km north of Wauchope roadhouse. The large rounded boulders are formed of Devils Marbles Granite, which intrudes the Hatches Creek Group. (M2189/23A)

Printed by Graphic Services Pty Ltd, Northfield, S.A.

CONTENTS

The authorship is indicated in parentheses; authors' initials are identified on the title page.

ABSTRACT . . . vii

INTRODUCTION (DHB) . . . 1
- Habitation and access . . . 1
- Climate . . . 1
- Vegetation . . . 1
- Topography and drainage . . . 2
- Previous investigations . . . 3
- Nomenclature . . . 3
- Acknowledgements . . . 3

OUTLINE OF GEOLOGY (DHB) . . . 5

WARRAMUNGA GROUP (DHB) . . . 6

HATCHES CREEK GROUP . . . 14
- Introduction (DHB) . . . 14
- Stratigraphy (DHB) . . . 15
  - Ooradidgee Subgroup . . . 15
  - Wauchope Subgroup . . . 18
  - Hanlon Subgroup . . . 20
  - Age . . . 21
  - Correlations . . . 21
- Sedimentology (IPS) . . . 21
  - Rooneys Formation . . . 22
  - Kurinelli Sandstone . . . 22
  - Taragan Sandstone . . . 24
  - Treasure Volcanics . . . 27
  - Unimbra Sandstone . . . 29
  - Yeeradgi Sandstone . . . 31
  - Coulters Sandstone . . . 33
  - Frew River Formation . . . 33
  - Errolola Sandstone . . . 35
  - Alinjabon Sandstone . . . 36
  - Lennee Creek Formation . . . 36
  - Canulgerra Sandstone . . . 36
  - Vaddingilla Formation and Yaddanilla Sandstone . . . 36
  - Petrography and provenance . . . 37
  - Discussion . . . 38
- Syndepositional tectonism (AJS) . . . 38
- Deformation (AJS) . . . 40
  - Structural domains . . . 40
  - Fold styles . . . 43
  - Faults . . . 43
  - Superimposed folds . . . 44
  - Deformation history . . . 45
- Regional metamorphism (DHB) . . . 45

PROTEROZOIC INTRUSIONS (DHB) . . . 45

GEOCHEMISTRY OF IGNEOUS ROCKS (DHB) . . . 49
- Geochemical features . . . 49
  - Felsic rocks . . . 50
  - Mafic rocks . . . 51
  - Lamprophyre . . . 52
  - Trace elements of economic significance . . . 53

PHANEROZOIC COVER (DHB) . . . 53
- Palaeozoic . . . 53
  - Cambrian . . . 53
  - Devonian . . . 54
- Mesozoic . . . 54
- Cainozoic . . . 54

GEOPHYSICAL INVESTIGATIONS (IGH) . . . 55
- Rock density . . . 55
- Regional gravity . . . 55
- Magnetic properties . . . 56
- Regional magnetic characteristics . . . 56
- Gamma-ray spectrometrics . . . 60
- Estimates of crustal thickness . . . 60

MINERAL RESOURCES AND METALLOGENESIS (DHB) 60
Tungsten 60
Hatches Creek tungsten field 60
Wauchope tungsten field 60
Mosquito Creek tungsten field 61
Juggler tungsten mine 61
Woodenjerrie tungsten mine 62
Gold 62
Copper and silver/lead 62
Uranium 63
Turquoise 63

ECONOMIC POTENTIAL (DHB) 63

SUMMARY OF GEOLOGICAL HISTORY (DHB) 65

REFERENCES 67

APPENDIX — CHEMICAL ANALYSES OF IGNEOUS ROCKS 70
Analytical methods 70
Analyses of igneous rocks (on microfiche in back pocket)

FIGURES

Frontispiece. Devils Marbles on the Stuart Highway.

1. Tectonic setting 1
2. Locality map 2
3. Jim Lewis Waterhole on Whistleduck Creek 2
4. Strike ridges and depressions in the northwest of the Davenport province . . . 3
5. Major fold outlined by ridge-forming sandstone units of the Hatches Creek Group . . . 4
6. Typical scenery in central part of the Davenport province 4
7. Scarp-forming sandstone and recessive felsic volcanic rocks, Hatches Creek Group . . . 5
8. Broad depression between mesas and flat-topped ridge 5
9. Structural domains of the Davenport province 6
10. Greywacke of the Warramunga Group 12
11. Photomicrograph of felsic lava, Warramunga Group 12
12. Fold in the Warramunga Group 12
13. Aerial view of unconformity between the Warramunga and Hatches Creek Groups in the Murchison Range . 13
14. Cleaved bedded tuff, Newlands Volcanics 14
15. Photomicrographs of felsic volcanic rocks, Hatches Creek Group . . 15
16. Distribution of felsic and mafic volcanic units of the Hatches Creek Group, and inferred major eruptive centres . 16
17. Coarse pyroclastic rocks within the Epenarra Volcanics 16
18. Bedded coarse tuffaceous/volcaniclastic rocks, Epenarra Volcanics . . 16
19. Epenarra Volcanics unconformably overlying Warramunga Group . . 17
20. Pebbly arenite, Taragan Sandstone 18
21. Ignimbrite, Treasure Volcanics 18
22. Aerial photograph showing the three major region-wide ridge-forming units of the Hatches Creek Group . . 19
23. Pebbly arenite in the lower part of the Unimbra Sandstone 20
24. Unimbra Sandstone at Unimbra Rockhole 20
25. Stromatolitic carbonates, Frew River Formation 20
26. Pillow lava, Kudinga Basalt 21
27. Stratigraphic correlation chart for the Davenport province and nearby regions . . . 22
28. Hatches Creek Group type-sections and sedimentological study sites . . . 23
29. Schematic representation of the type section for the Rooneys Formation . . . 24
30. Key to symbols used in Figs 29, 32, 38, 39, 50, 53 and 56 24
31. Hummocky cross-stratification, Rooneys Formation 24
32. Top 36 m of Kurinelli Sandstone underlying the type section for the Taragan Sandstone . . . 25
33. Large-scale wedge-shaped cross-beds in Kurinelli Sandstone . . . 25
34. Prolapsed cross-bedding in Kurinelli Sandstone 26
35. Limonite pseudomorphs after gypsum in Kurinelli Sandstone . . . 26
36. Load casts in Kurinelli Sandstone 26
37. Palaeocurrent data for Kurinelli Sandstone 27
38. Measured sections of Taragan Sandstone in the Murray Downs Dome . . . 28
39. Type section of the Taragan Sandstone 29
40. Lateral accretion bedding, Taragan Sandstone 30
41. Sand volcanoes at top of the Taragan Sandstone 30
42. Plan view of sand volcano 30
43. Sand volcano with petal-like structure 31
44. Taragan Sandstone palaeocurrents 31
45. Gently dipping bedding plane of arenite within the Treasure Volcanics . . . 31
46. Train of megaripples 32
47. Detail of megaripple 32
48. Megaripple transitional into lunate and linguoid ripples 32
49. Palaeocurrent data for Unimbra Sandstone and younger sandstone units of the Hatches Creek Group . . 32
50. Type section of Coulters Sandstone 33
51. Low-angle cross-bedding in Coulters Sandstone 34

52. Large-scale planar cross-beds, trough cross-beds, and reactivation surfaces in Coulters Sandstone . . . 34
53. Transition beds mapped as basal Frew River Formation 34
54. Large wave ripples in Frew River Formation 35
55. Algally laminated and algally fixed wave ripples, Frew River Formation 35
56. Schematic section of Alinjabon Sandstone 36
57. Two sets of wave ripples in Canulgerra Sandstone 37
58. Arenite modal compositions 38
59. Isopach maps and syndepositional faults, Hatches Creek Group 39
60. Aerial photograph and map of northwest-trending folds in northern part of Davenport province . . . 41
61. Aerial photograph and map of northwest-trending fold buckled by later northeast-trending fold . . . 42
62. Axial-surface penetrative cleavage in Frew River Formation 43
63. Map of disharmonic folding within the McLaren Syncline 44
64. Small steeply plunging folds in Lennee Creek Formation 44
65. Disharmonic fold in Kurinelli Sandstone 44
66. Fault block (horse) of Alinjabon Sandstone thrust over Lennee Creek Formation 44
67. Photomicrographs of dacitic and rhyolitic granophyre 48
68. Elkedra Granite overlain by flat-lying Cambrian strata 48
69. Stellate clusters of tourmaline crystals in quartz vein cutting Elkedra Granite 49
70. The Devils Marbles, Stuart Highway 50
71. Histogram of silica contents for chemically analysed igneous rocks from the Davenport Province . . . 50
72. Variation diagrams of selected major oxides and trace elements for felsic igneous rocks 52
73. Abundances of selected major oxides and trace elements plotted against M number for mafic igneous rocks . . 52
74. Conglomerate with interbedded sandstone, Andagera Formation 53
75. Stereoscopic pair of aerial photographs of dissected Cambrian river terraces 54
76. Mesozoic? conglomerate lying unconformably on Unimbra Sandstone 54
77. Bouguer anomaly contours, Davenport province and surrounding area 55
78. Bouguer anomaly contours, Davenport province 56
79. Gravity anomalies over granite, and model sections 58
80. Aeromagnetic contours, Davenport province and surrounding area 58
81. Interpretation of solid geology from aeromagnetic data 59
82. Estimated thickness of cover rocks in *Bonney Well* 59
83. Gamma-ray spectrometric total-count contours for *Bonney Well* 60
84. Distribution of mineral deposits in the Davenport province 61
85. Tungsten mines 62
86. Gold mines 63
87. Distribution of the Frew River Formation 64

TABLES

1. Details of Proterozoic stratigraphy, Davenport province 7
2. Details of Proterozoic intrusions, Davenport province 46
3. Chemically analysed igneous rocks 51
4. Summary of density measurements (from Hone & others, in preparation) 55
5. Summary of laboratory magnetic susceptibility measurements (from Hone & others, in preparation) . . . 57

ABSTRACT

The Davenport province, situated between the Proterozoic Tennant Creek Au–Cu–Bi metalliferous province and Arunta Inlier, consists of sedimentary, volcanic and intrusive rocks which are overlapped by flat-lying Palaeozoic sediments of the Georgina and Wiso Basins. The oldest rocks seen are turbiditic sediments and subordinate chert and felsic volcanics of the 1870 Ma-old Warramunga Group. This group, which is exposed only in the north, was folded, weakly metamorphosed, intruded by granite, and eroded before being overlain by the Hatches Creek Group, the main component of the Davenport province.

The Hatches Creek Group is a folded sedimentary and bimodal volcanic sequence, at least 10 km thick, comprising three subgroups, twenty formations, and two named members; felsic volcanics in the oldest subgroup were probably erupted 1810–1820 Ma ago. The group is correlated with part of the Tomkinson Creek beds north of Tennant Creek and probably with Division 3 of the Arunta Inlier. The sedimentary rocks include quartz-rich to lithic and feldspathic sandstone, conglomerate, siltstone, finer-grained rocks, and minor carbonates, some of which are stromatolitic. Environments were mainly fluvial (alluvial fan, braided stream, meandering stream) in the lower part of the group and shallow marine (including tidal) in the middle and upper parts. Felsic and mafic volcanism, comagmatic sill emplacement, and probably faulting accompanied sedimentation, which kept pace with subsidence. An extensional ensialic tectonic setting is envisaged. The sequence was deformed, regionally metamorphosed to mainly greenschist facies, and subsequently intruded by 1660 Ma-old granite. The deformation was of thick-skinned type, and involved two episodes of tight, upright, concentric folding.

Chemically, the felsic volcanics of the Hatches Creek Group differ from those of the Warramunga Group (which resemble the 1865 Ma-old Leichhardt Volcanics in the Mount Isa Inlier) in having higher contents of Ti, P, Th, U and especially Zr, Nb and Y, and lower Ca, Al, Sr and V. The mafic volcanics of the Hatches Creek Group are continental tholeiites.

Geophysical data show that the younger granites of the province correspond to marked gravity lows; that units within the Hatches Creek Group can be traced in the subsurface using contoured aeromagnetics; and that the felsic igneous rocks are moderately radioactive.

Mineralisation is largely restricted to the lower part of the Hatches Creek Group, where there are quartz veins with wolframite and scheelite probably related to granite intrusions, and auriferous quartz veins that may have formed during regional metamorphism. Total recorded production amounts to about 4500 t tungsten concentrates, mainly from the Hatches Creek and Wauchope tungsten fields, and 15 kg gold. Small quantities of copper, silver-lead, bismuth, and uranium have also been mined.

INTRODUCTION

(DHB)

The Davenport province is an area of folded sedimentary rocks and bimodal volcanics and intrusives forming the southern part of the Proterozoic Tennant Creek Inlier in central Australia (Fig. 1). It is regarded as a tungsten–gold metallogenic province, although no major mineral deposits have been found, as it incorporates the Hatches Creek, Wauchope and Mosquito Creek tungsten fields and the Kurundi goldfield, and includes rocks similar to those in the Tennant Creek gold–copper–bismuth metallogenic province to the north. The Proterozoic Arunta Inlier lies to the southwest and south. Palaeozoic marine sediments of the Georgina Basin to the east and south and the Wiso Basin to the west overlie the Proterozoic rocks around the margins of the Davenport province.

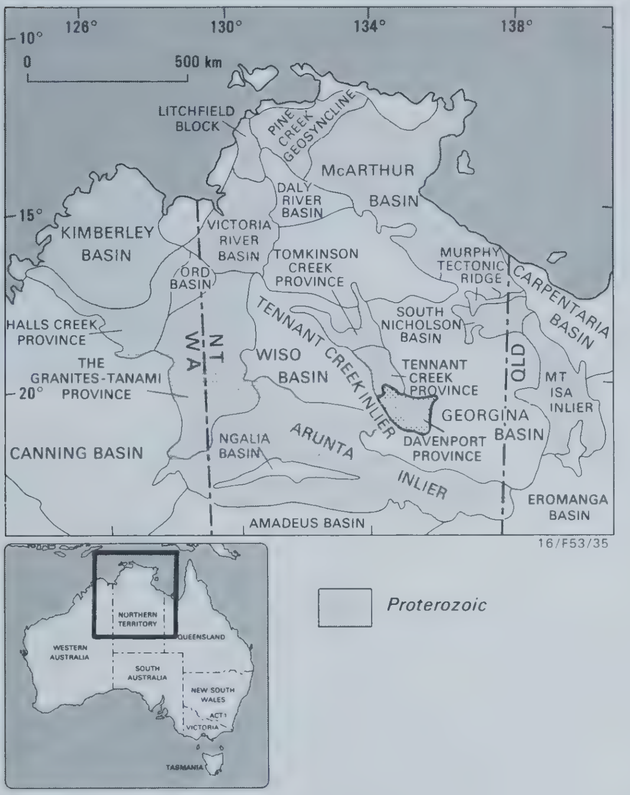

Fig. 1. Tectonic setting.

This bulletin and accompanying 1:250 000 geological map are based on fieldwork carried out by geologists from the Bureau of Mineral Resources (BMR) and the Northern Territory Geological Survey (NTGS) in 1981–1983 as part of the Davenport project. The aims of this project were to determine the stratigraphy, structure, geological history, and tectonic setting of the Davenport province and to assess its mineral potential; to link the geology of the Arunta Inlier to the south with the economically important Tennant Creek metallogenic province to the north, and to aid the understanding of the basement beneath the Palaeozoic Georgina and Wiso Basins. The geologists involved were D. H. Blake, A. J. Stewart and I. P. Sweet (BMR), and S. Wyche and C. L. Horsfall (NTGS). Results of the work include Preliminary Edition and First-Edition 1:100 000 geological maps, reports and commentaries of HATCHES CREEK REGION[1] (Blake & Wyche, 1983; Blake & others, 1986a), KURUNDI REGION (Stewart & Blake, 1984 and 1986); DEVILS MARBLES REGION (Wyche & Blake, 1984; Wyche & others, 1987), and ELKEDRA REGION (Blake & Horsfall, 1984 and 1987). In addition, Blake & others (1986b) have presented a geological synthesis of the Hatches Creek Group, the main component of the Davenport province, and Stewart (in press) has described the structure. Stratigraphic correlations between the Davenport province and other parts of the Tennant Creek Inlier have been discussed by Blake (1984).

Concurrent investigations have included a stream-sediment geochemical orientation survey by BMR in 1982, which studied the dispersion of trace elements in areas of known and potential mineralisation in the province (Hoatson & Cruickshank, 1985); updating of the 1:250 000 standard geological sheets by NTGS; airborne magnetic and radiometric surveys in 1981 of Hatches standard 1:100 000 Sheet and *Bonney Well*[1] by BMR (data available from the Australian Government Printer Copy Service) and *Barrow Creek* by NTGS (data available from the Department of Mines & Energy, N.T.); and detailed gravity and carborne magnetometer and radiometric traverses in 1982 by BMR to supplement the regional geophysical data. Physical properties of rock units in the province have been determined by Hone & others (in preparation). An isotopic study of igneous rocks to establish a geochronological framework for the province was commenced in 1984 by R. W. Page (BMR); preliminary results are given in Blake & Page (in press).

Habitation and access

There are no towns in the Davenport province. Permanent settlements are located at Wauchope and Wycliffe Well roadhouses on the Stuart Highway, which crosses the western part of the area, and at McLaren Creek homestead in the northwest and Singleton, Murray Downs, Kurundi, Epenarra, and Elkedra homesteads in the central part (Fig. 2). These homesteads, and the abandoned Hatches Creek mining settlement, are connected by unsealed roads to the Stuart Highway. Other unsealed roads and vehicle tracks (mainly along fences and to water bores) help provide vehicular access to most parts of the province. Cross-country travel is impeded by long steep-sided ridges with few gaps (and by countless fire-hardened stakes). Airstrips suitable for light aircraft are situated close to the permanent settlements and near Hatches Creek and some water bores.

Climate

The Davenport province has a semi-arid tropical climate. Data for Barrow Creek to the south and Tennant Creek to the north indicate an average annual rainfall of about 300 mm, most of which is received in the period from November to March. On average there are about 30 rainy days a year. Maximum temperatures of over 40° are common in the summer months and minimum temperatures of less than 10° in winter. Frosts occur occasionally in July. Marked diurnal fluctuations in temperature are normal. For a general discussion of the climate, see Slatyer (1962).

Vegetation

The dominant vegetation is spinifex with sparse low trees and shrubs (Perry & Lazarides, 1962). Eucalypt trees line some of the larger watercourses, especially near waterholes (Fig. 3). A variety of grasses, and also small stands of mulga and gidgea, grow on plains and valley floors. Patches of 'turpentine' bush are present locally on the sides of ridges.

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[1] Names of 1:100 000-scale geological sheets are printed in capital letters, those of standard 1:250 000 sheets are in italics.

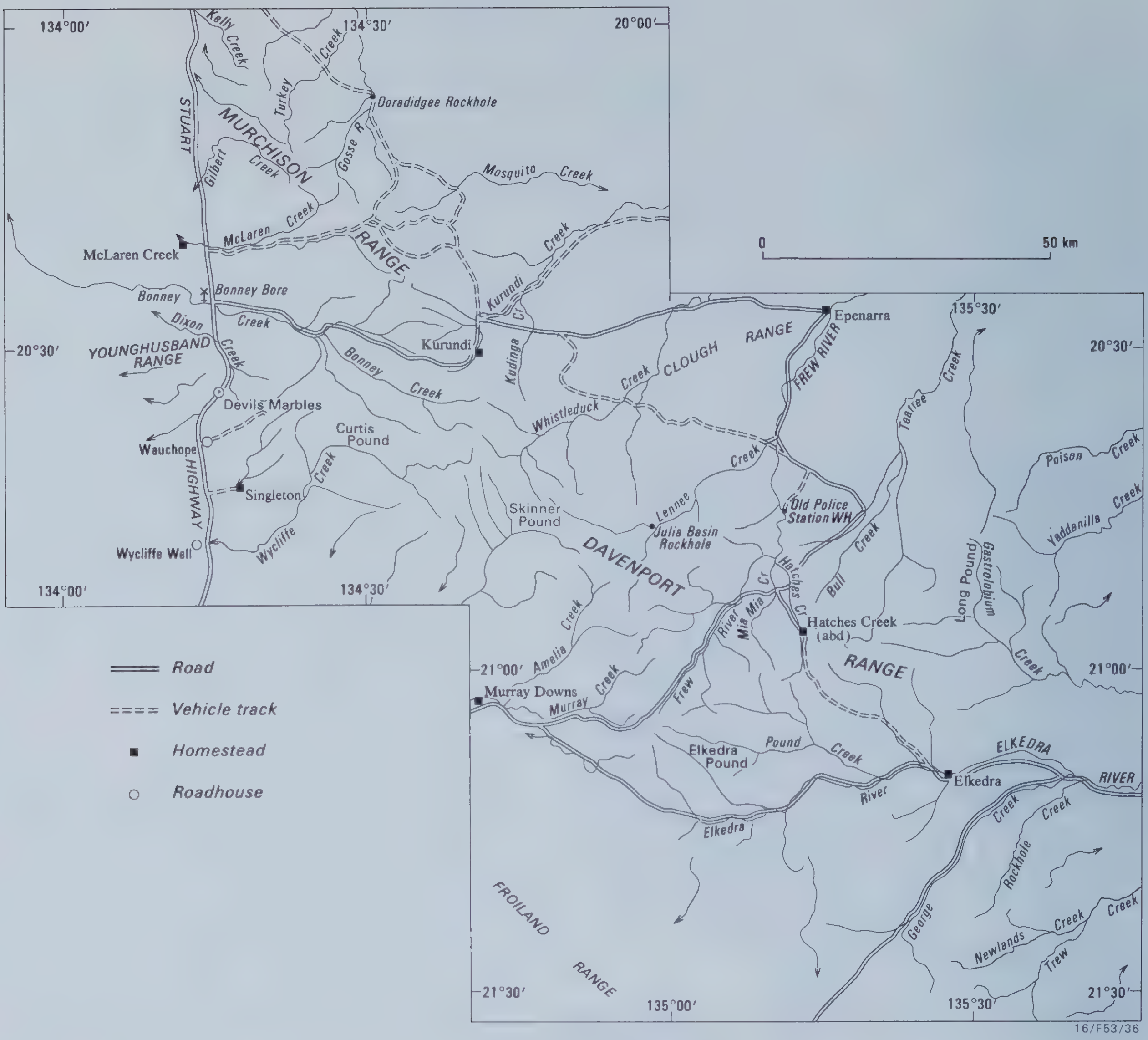


Fig. 2. Locality map.

Fig. 3. Jim Lewis waterhole on Whistleduck Creek, KURUNDI REGION (at GR MT992343). (M2695/26A)

Topography and drainage

The Davenport province lies within the northern plains and uplands region of the Alice Springs area (Mabbutt, 1962), and consists of a northwesterly trending belt of low ranges flanked by extensive plains. It varies in altitude from about 590 m to a little less than 300 m above sea level. The ranges are formed mainly of long and commonly sinuous strike ridges with flat tops (the Ashburton Surface of Hays, 1967) and steep sides, separated by intervening broad to narrow valleys and depressions with flat to gently sloping or undulating floors (Fig. 4). The local relief rarely exceeds 100 m. The ridges are of resistant Proterozoic sandstone, and outline major folds (Fig. 5). As well as the planated ridges, there are cuestas, hog-back ridges, rounded hills, pyramidal hills, dissected terraces, incised fans, mesas, and, in the far south, scarp-bounded plateaus (Figs 4–8). The mesas, plateaus, and dissected terraces are capped by flat-lying Phanerozoic sediments. Northwesterly trending low sand ridges cross the plains to the east and west of the ranges.

Several large streams radiate outwards from the ranges and flood-out and disappear on the surrounding plains (Fig. 2). The main water courses are the westerly draining Bonney Creek, the northerly draining Gosse and Frew Rivers, and the easterly draining Elkedra River. Numerous permanent, semi-permanent, and seasonal waterholes, some of which are several hundreds of metres long (Fig. 3), are present along the main water courses and also along many of the smaller creeks within the ranges. Several water bores have been drilled, but some are suitable only for stock. Jones & Quinlan (1962) have given a general account of water resources.

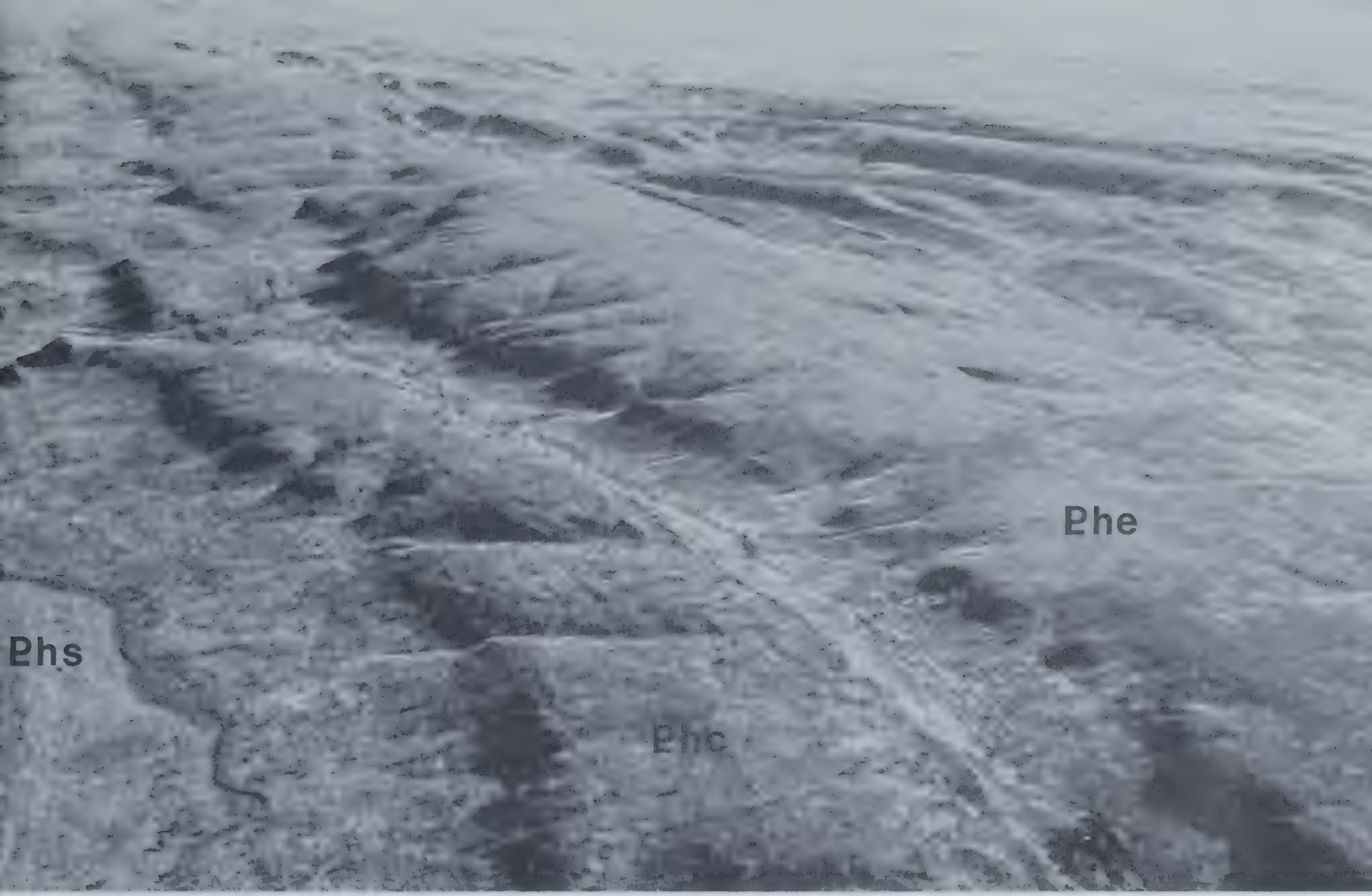


Fig. 4. Strike ridges and depressions in the northwest of the Davenport province. View from the south across the McLaren Creek Syncline in DEVILS MARBLES REGION. The main ridges, up to 80 m high, are formed of Unimbra Sandstone (Ᵽhs), Coulters Sandstone (Ᵽhc), and Errolola Sandstone (Ᵽhe) of the Hatches Creek Group. S. Wyche (M2695/16A)

Previous investigations

The first geological observations in the Davenport province were made during exploration and prospecting expeditions between 1895 and 1906 (Brown, 1895, 1896, 1903; Davidson, 1905; Murray, 1907). Mining at Hatches Creek began in 1914 and shortly afterwards Oliver (1916) inspected the area. The Hatches Creek and Wauchope tungsten fields were investigated in 1940 by AGGSNA (1941) and re-examined in 1949 by Sullivan (1951, 1952, 1953a, 1953b). The tungsten deposits of the Mosquito Creek area east of the Murchison Range, discovered in 1951, were described by Joklik & Tomich (1951) and Bell (1953). A uranium prospect a few kilometres to the southwest, Munadgee, was examined by Lord (1955, 1956). Several aspects of the geology of the region were discussed by Hossfeld (1954).

The only previous systematic geological investigation of the whole province was a broad reconnaissance by BMR geologists in 1956 (Smith & others, 1961). In the same year, Ryan (1961) studied in detail the Hatches Creek tungsten field. Summaries of this work are included in the explanatory notes for *Frew River* (Smith, 1964), *Barrow Creek* (Smith & Milligan, 1964), *Elkedra* (Smith & Milligan, 1966), and *Bonney Well* (Smith, 1970). More recently, Crohn (1976) and Roarty (1977) briefly described the geology and mineralisation.

Nomenclature

Terms used in this report are defined in the Glossary of Geology (Bates & Jackson, 1980).

Proterozoic sandstones are classified according to the general scheme of Pettijohn & others (1973), based on field-determined proportions of grain-types. Sandstones that consist very largely of quartz grains are termed quartz arenites; those with appreciable though subordinate amounts of other grains are termed lithic or feldspathic arenites, as appropriate. Thin-section studies by I. P. Sweet have shown that most of the rocks described as quartz arenites in this Bulletin lie within the sublitharenite field.

Acknowledgements

We are grateful for the hospitality and assistance provided by the residents of the region during the course of the project. Special thanks are due to Mr and Mrs P. Saint of Kurundi station, Mr and Mrs K. Page of Murray Downs station, and Mr and Mrs R. Driver of Elkedra station. We also acknowledge the contributions of S. Wyche and C. L. Horsfall, NTGS, who were members of the 1981 and 1982 mapping parties.

Aerial photographs are reproduced by permission of the Director, Division of National Mapping, Department of Resources and Energy, Canberra; Crown Copyright reserved. Aeromagnetic data for *Barrow Creek* shown in Fig. 80 are reproduced with permission of the Chief Geologist, Northern Territory Geological Survey, Department of Mines and Energy, Northern Territory.

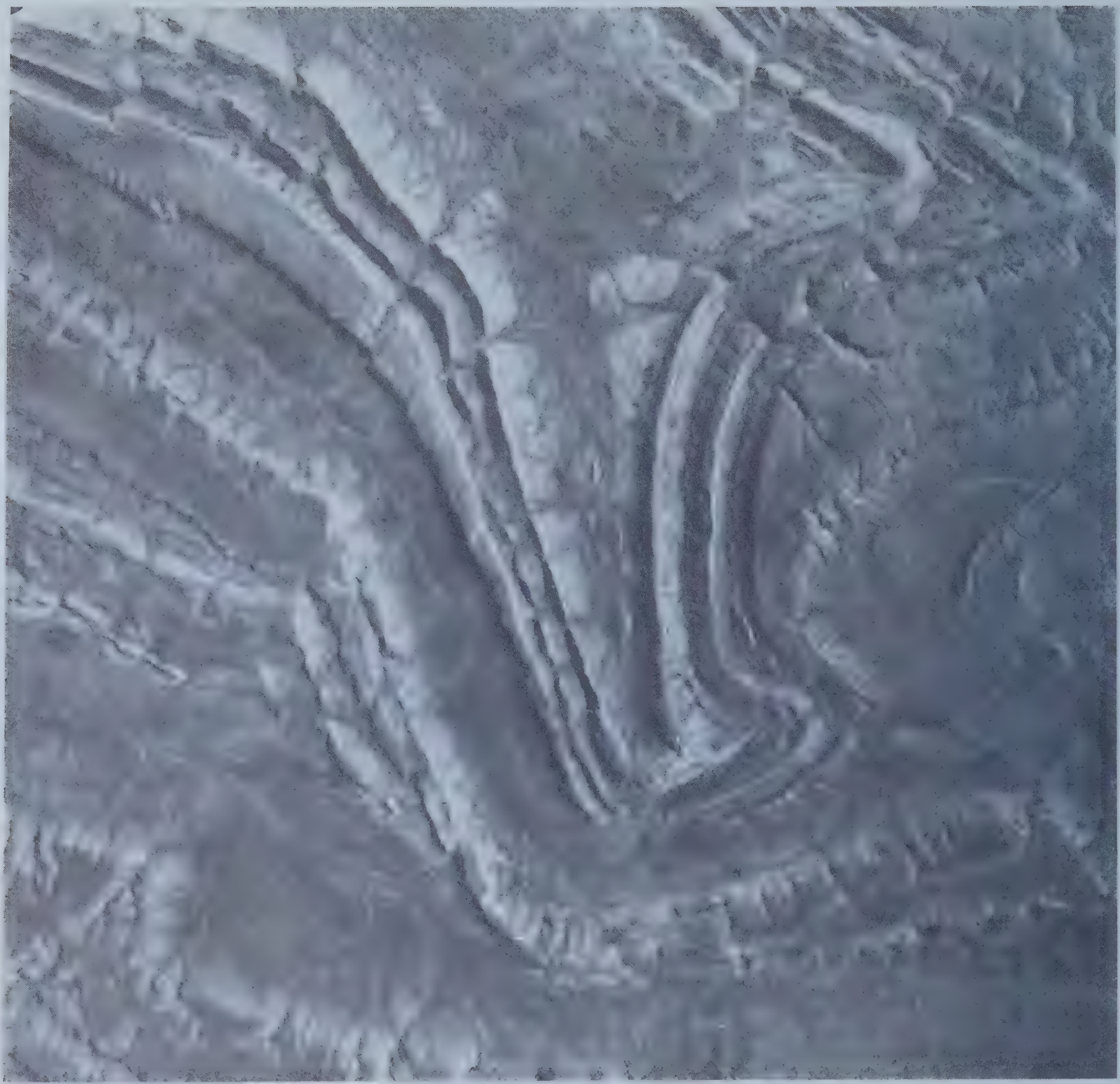


Fig. 5. Vertical aerial photograph of major fold outlined by ridge-forming sandstone units of the Hatches Creek Group in the central part of the Davenport province. The area shown is 5.5 km across from east to west (right to left). (Hatches, run 10, No. 1000, CAG/C14, 16.9.1980)

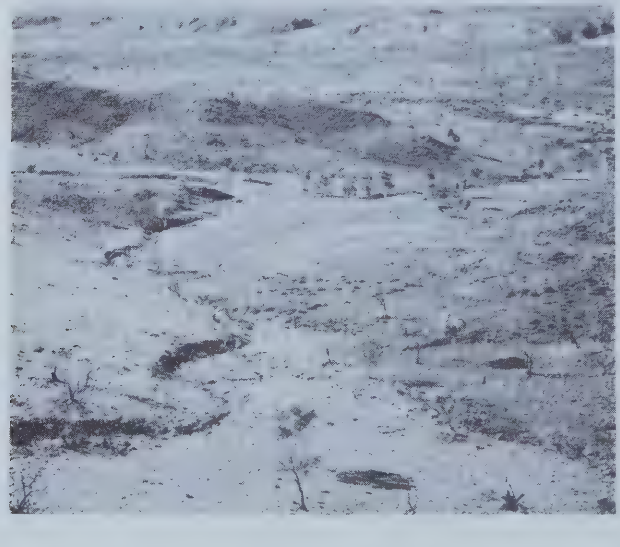


Fig. 6. Typical scenery in the central part of the Davenport province, showing an incised alluvial fan in front of low hills bordering a kilometre-wide depression, with a flat-topped ridge up to 100 m high in the background. The low hills are formed of Kudinga Basalt (partly overlain by Tertiary gravel); the depression is underlain by both Kudinga Basalt and Frew River Formation; and the far ridge is of Coulters Sandstone — all formations of the Proterozoic Hatches Creek Group. View east from GR NS055830, HATCHES CREEK REGION. (M2474/34)

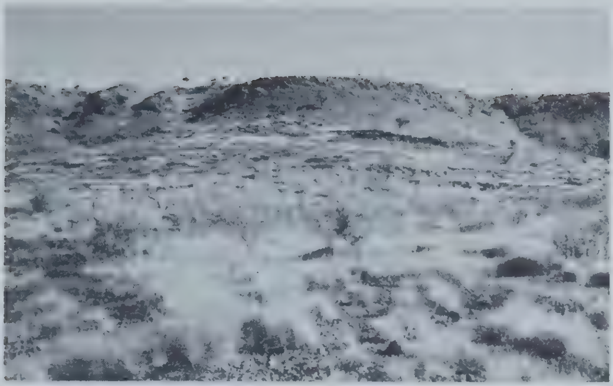


Fig. 7. Scarp-forming sandstone, with undulating terrain in the foreground developed on recessive felsic volcanic rocks; Epenarra Volcanics of the Proterozoic Hatches Creek Group in KURUNDI REGION (near GR MT785295). (M2473/11)

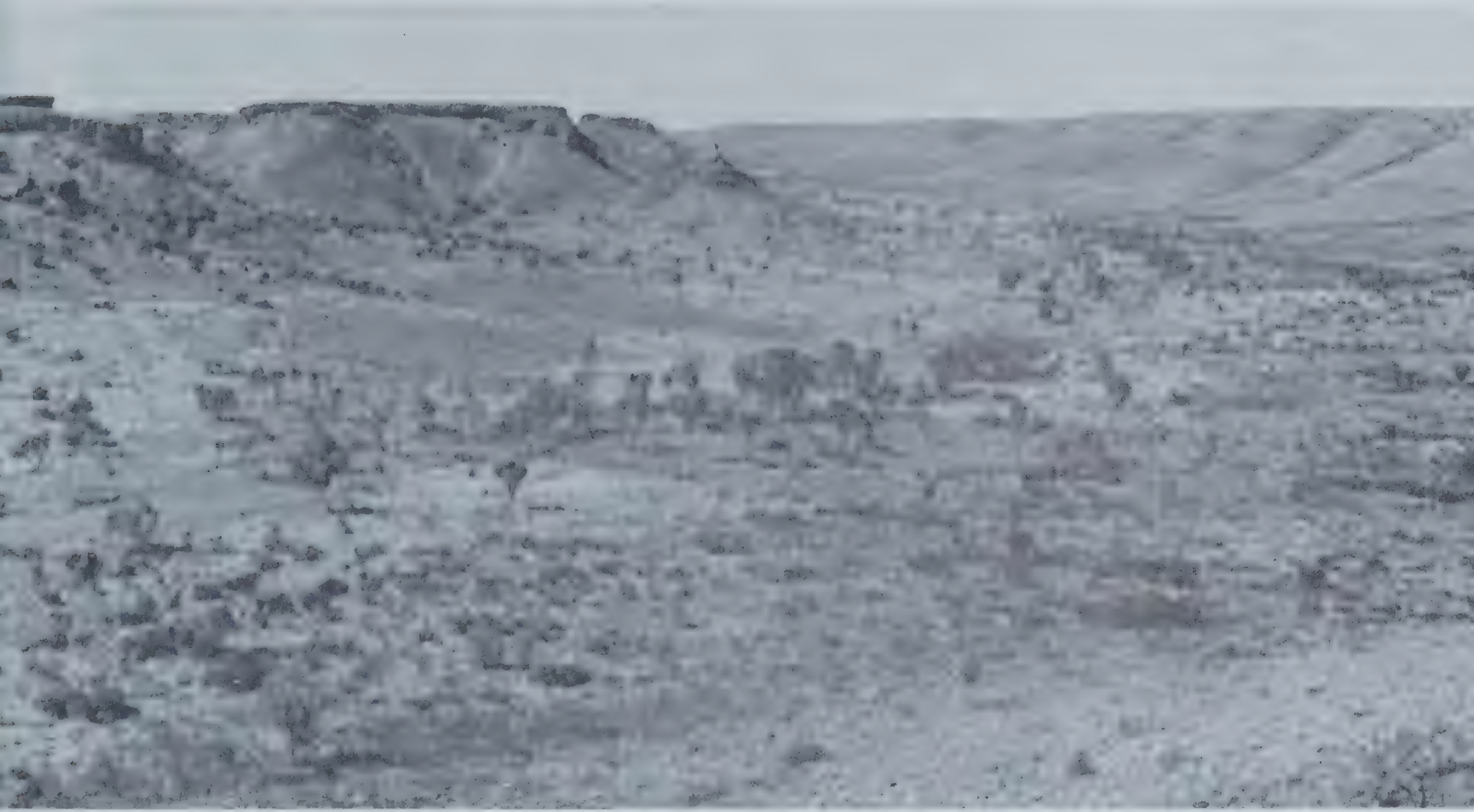


Fig. 8. Broad depression between mesas of flat-lying Cambrian conglomerate capping recessive Proterozoic felsic volcanics (Newlands Volcanics) to left and flat-topped ridge of Proterozoic sandstone (Coulters Sandstone) in background to right. The maximum relief here is less than 100 m. View southeast from GR NS525410, ELKEDRA REGION. (M2536/27)

OUTLINE OF GEOLOGY

(DHB)

Two major stratigraphic units, the Warramunga and Hatches Creek Groups, and several granitic intrusions, all of which are Proterozoic, crop out in the Davenport province. Six structural domains have been identified (Fig. 9)—the Kelly High, the Ooradidgee, Pingelly, Edmirringee, and Taragan Blocks, and the Wauchope Fold Belt.

The oldest rocks exposed are those of the 1870 Ma-old Warramunga Group. This group, which crops out in the north, is represented mainly by turbiditic greywacke and siltstone, but also includes chert and felsic volcanics. It was tightly folded and intruded by the Hill of Leaders Granite and unnamed granite before being overlain unconformably by the Hatches Creek Group.

The Hatches Creek Group crops out extensively throughout the province. It is an ensialic sequence at least 10 km thick of sedimentary and bimodal volcanic rocks which were intruded by felsic and mafic sills and subsequently folded, faulted, and metamorphosed before being intruded by Elkedra Granite (probably emplaced at about 1660 Ma), Devils Marbles Granite, and unnamed granite. Felsic volcanics in the lower part of the group were probably erupted 1810-1820 Ma ago. The Hatches Creek Group is correlated with part of the Tomkinson Creek beds exposed in the north of the Tennant Creek Inlier.

The main sedimentary rocks of the Hatches Creek Group are ridge-forming silicified quartz, feldspathic and lithic

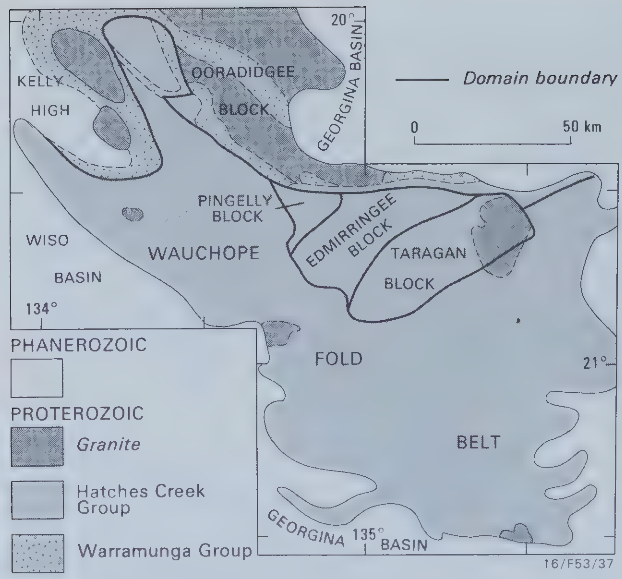


Fig. 9. Structural domains, Davenport province.

arenites and conglomerate, and recessive friable arenites, siltstone, shale, mudstone, and carbonates. Fluvial to shallow-marine deposition is indicated by cross-bedding, ripple marks, bedding planes with siltstone or mudstone pellets, stromatolites, mud-cracks, and halite and gypsum casts. Rapid deposition is suggested by pebbles, detrital clay, and feldspar in arenites, and the widespread occurrence of prolapsed (=recumbent fold-type) cross-bedding. Isopach evidence shows that some faulting probably took place during deposition. Felsic and mafic volcanics, and granophyre and dolerite/ gabbro sills probably similar in age to the volcanics, are interlayered with the sedimentary rocks. The felsic volcanics are predominantly lavas and ignimbrites, but also include bedded tuffs and agglomerates. Mafic volcanics are represented mostly by tabular basaltic lava flows. The volcanism was largely subaerial.

The Hatches Creek Group is divided into three subgroups: from oldest to youngest, the Ooradidgee, Wauchope, and Hanlon Subgroups. Formations of the Ooradidgee Subgroup typically interfinger with one another; they consist largely of alluvial fan, fluvial, and deltaic sedimentary rocks and volcanics which were erupted from several volcanic centres. Most formations of the two younger subgroups form a regularly layered succession laid down in mainly shallow-marine shelf and marginal marine environments; the Wauchope Subgroup includes substantial felsic and mafic volcanics, whereas the overlying Hanlon Subgroup is almost devoid of volcanic rocks.

The felsic volcanics of the Hatches Creek Group and associated granophyre sills have SiO_2 contents in the range 63–77%. They are potassic, generally having 3–7% K_2O and K_2O/Na_2O values greater than 1.5. Their Ti, P, Th, U, Zr, Nb, and Y contents are appreciably higher than those of felsic volcanics in the Warramunga Group. Analysed mafic lavas and sills are classified as continental tholeiites, although they have relatively low contents of Ti, P, Zr, and Y.

Some time after sedimentation and volcanism, but before the emplacement of younger granites, which include the Devils Marbles Granite and the 1660 Ma-old old Elkedra Granite, the Hatches Creek Group was deformed and regionally metamorphosed mainly to greenschist facies. The deformation involved two folding episodes and also strike-slip and reverse faulting which probably took place along previously existing synsedimentary normal and transfer faults. The folds formed at this time are typically upright, open to close in profile, sinuous in trend, and concentric in style, as shown on the accompanying 1:250 000 geological map. They are characteristically tens of kilometres long and several kilometres wide, much larger than the earlier folds in the Warramunga Group (which typically have wavelengths of about one kilometre). The first-formed folds affecting the Hatches Creek Group generally have northwesterly trends, whereas the later folds have northerly to northeasterly trends. These later folds buckled some of the earlier folds, and in the southeast produced interference domes, saddles, and basins. The folding was thick-skinned in type, as it involved the Warramunga Group as well as the Hatches Creek Group, and no region-wide decollement layer is evident. Cleavage related to the folding is well developed locally, and is particularly intense on the northeastern and southeastern margins of the province. Schist previously mapped as Archaean? Arunta Complex in the far southeast represents deformed Hatches Creek Group rocks and intrusive granophyre.

The tungsten deposits in the Davenport province are wolframite and scheelite-bearing quartz veins, some of which also contain copper, bismuth, and molybdenum minerals. The veins cut the Ooradidgee Subgroup and granite. They appear to postdate the folding of the Hatches Creek Group, and are thought to result from late hydrothermal solutions emanating from post-deformation granite plutons. Gold occurs in quartz veins in the northern half of the province; these veins may have formed when the Hatches Creek Group was deformed and metamorphosed. Small silver/lead deposits located within the Ooradidgee Subgroup in northwest ELKEDRA REGION, where galena-bearing quartz veins cut basalt lavas, may also be related to this deformation.

During the late Proterozoic, the Davenport province was eroded to a plain of very low relief, represented by the present-day flat ridge tops (the Ashburton surface). Slight uplift induced differential erosion which resulted in valleys generally less than 100 m deep being excavated in the less resistant rocks.

In the Cambrian, shallow-marine sediments were deposited around the margins of the province, while fluvial sand and gravel formed river terraces and floodplains partly filling valleys in the central part, which appears to have remained above sea level throughout the Phanerozoic. Although now largely eroded, some remnants of the Cambrian river terraces are preserved, and together with the slightly higher flat-topped ridges, may be the oldest persisting landforms on earth.

Sandstone of possibly Devonian age is exposed in the far west, and there are outcrops of possibly Mesozoic sandstone to the east. Plains and valley floors are covered by non-marine surficial Cainozoic sediments.

WARRAMUNGA GROUP

(DHB)

The oldest rocks exposed in the Davenport province are greywacke, lithic arenite, siltstone, shale, chert, jaspilite, and felsic volcanics of the Warramunga Group (Table 1). These crop out as low hills and ridges in the northern part of the province and more extensively farther north, around Tennant Creek. They are generally deeply weathered and iron-stained to bleached. Greywacke beds are commonly graded and in places show cross-bedding (Fig. 10). The felsic volcanics

TABLE 1. DETAILS OF PROTEROZOIC STRATIGRAPHY, DAVENPORT PROVINCE.

Unit and map symbol (thickness in metres)	*Lithology*	*Relationships*
HATCHES CREEK GROUP HANLON SUBGROUP		
Yaddanilla Sandstone Ᵽhy (1000?)	Quartz arenite and feldspathic/lithic arenite: white to pale grey, medium-grained, medium-bedded, cross-bedded, with mudstone pellets on some bedding planes.	Conformable on Vaddingilla Formation.
Vaddingilla Formation Ᵽhv (800)	Siltstone, shale, arenite. Arenite: generally reddish brown; friable; variably feldspathic/lithic and micaceous; fine to medium-grained; cross-bedded in places.	Conformable on Canulgerra Sandstone; overlain conformably by Yaddanilla Sandstone.
Canulgerra Sandstone Ᵽhu (500)	Quartz arenite, siltstone, shale; minor feldspathic/lithic arenite; rare polymictic conglomerate. Arenite: mainly pale pink, white, or iron-stained, medium to coarse-grained, rather poorly sorted, and medium to thin-bedded; variable but generally sparse lithic or feldspathic content; cross-bedding, ripple marks, and bedding planes with mudstone/siltstone flakes common; pebbles present in some beds. Siltstone and shale: reddish brown, purple or white; thin bedded; variably micaceous; rarely calcareous.	Conformable on Lennee Creek Formation; overlain conformably by Vaddingilla Formation.
Lennee Creek Formation Ᵽhl (700–1500)	Shale, siltstone, lithic/feldspathic arenite; minor mudstone, claystone, quartz arenite. Shale, siltstone, mudstone and claystone: grey, iron-stained, or bleached; thin-bedded to laminated; variably micaceous; calcareous beds and chert concretions present in places. Arenite: friable, with abundant clayey matrix, to quartzose and silicified; also micaceous; fine to medium-grained; thin to medium-bedded; commonly cross-bedded.	Conformable on and may partly interfinger with Alinjabon Sandstone; overlain conformably by Canulgerra Sandstone.
Alinjabon Sandstone Ᵽhi (300–840)	Feldspathic/lithic arenite, quartz arenite, siltstone, shale; minor altered mafic lava, greywacke, chert, ironstone. Arenite: white, grey or pink; friable to silicified; rarely micaceous; mainly fine to medium-grained and medium to thin-bedded; commonly cross-bedded; some gritty and pebbly beds, ripple marks, bedding planes with siltstone pellets, and slump structures. Siltstone and shale: grey, purplish, iron-stained, or bleached; thin-bedded to laminated; variably micaceous; weakly calcareous in places. Mafic lava: reddish brown, much altered and weathered; may range in composition from basalt to trachyte.	Conformable on Errolola Sandstone; overlain conformably by and may locally interfinger with basal part of Lennee Creek Formation.
Errolola Sandstone Ᵽhe (100–1200+)	Feldspathic/lithic arenite, quartz arenite; minor conglomerate; rare claystone. Arenite: white, pink, grey, or iron-stained; silicified to friable; mainly medium-grained, well sorted, medium to thin-bedded, and cross-bedded; ripple marks and bedding planes with mudstone/siltstone flakes present in places; rare pebbles mainly of vein quartz. Conglomerate: present in upper part of formation in far northwest; contains pebbles, cobbles and boulders of silicified quartz arenite and minor vein quartz and jasper.	Conformable on Kudinga Basalt; overlain conformably by Alinjabon Sandstone.

TABLE 1. (continued)

Unit and map symbol (thickness in metres)	*Lithology*	*Relationships*
WAUCHOPE SUBGROUP Kudinga Basalt Ꝑhb (50–770)	Basalt; subordinate feldspathic/lithic arenite and quartz arenite; minor trachyte; rare volcaniclastic arenite and siltstone, chert. Basalt: forms tabular lava flows; bluish to greenish grey where not weathered, but mostly lateritised; rarely porphyritic; commonly amygdaloidal; epidotic and/or actinolitic alteration generally evident. Arenite: mainly pale to dark grey or iron-stained, silicified, medium-grained, medium-bedded, and cross-bedded; ripple marks, pebbles (rare) and micaceous beds in places. Trachyte: forms lava flows in SE KURUNDI REGION; with phenocrysts of orthoclase.	Conformable on Frew River Formation and, in NW, on Coulters Sandstone; overlain conformably by Errolola Sandstone.
Frew River Formation Ꝑhf (0–600)	Arenite, siltstone, mudstone, limestone, dolomite; possible altered mafic lava in far SE (GR NS670255, ELKEDRA REGION). Siltstone: generally weathered, bleached, variably clayey, micaceous, calcareous, and siliceous; mostly thin-bedded to laminated; halite casts (at GR NT010835, HATCHES CREEK REGION). Arenite: grey, brown, yellow, buff; mainly friable, feldspathic/lithic, medium to fine-grained and thin to medium-bedded, with clayey or carbonate matrix; rarely silicified and quartzose; cross-bedding, ripple marks, and bedding planes with mudstone/siltstone pellets common; slump structures present in places; rare mudcracks and halite casts. Limestone and dolomite: grey, pink, yellow, or iron/manganese-stained; commonly stromatolitic; form manganiferous and hematitic gossans in southeast.	Conformably on Coulters Sandstone; overlain conformably by Kudinga Basalt.
Coulters Sandstone Ꝑhc (140–1000+)	Quartz arenite, feldspathic/lithic arenite; minor siltstone, micaceous arenite, altered mafic lava. Arenite: white, pale pink and pale grey, or iron-stained; silicified to friable; generally sparse clay matrix; mostly medium-grained and well sorted; thick-bedded (especially near base) to thin-bedded (mainly near top); generally cross-bedded; ripple marks common in upper part; grit, granules and pebbles, mainly of vein quartz, and also bedding planes with mudstone/siltstone pellets present in places.	Conformable and locally unconformable on Yeeradgi Sandstone, Newlands Volcanics, Arabulja Volcanics; overlain conformably by Frew River Formation and, in NW, by Kudinga Basalt. May be intruded by dolerite in far SE.
Arabulja Volcanics Ꝑhj (0–500)	Felsic lava; minor tuff, ashstone, possible ignimbrite. Felsic lava: forms 2 or more flows; mainly pink, purple, or reddish brown; invariably much altered; consists of equant phenocrysts up to 5 mm across of alkali feldspar (generally pseudomorphed) ± quartz ± pseudomorphed ferromagnesian minerals in very fine-grained quartzofeldspathic groundmass.	Conformable on, and probably interfingers with Yeeradgi Sandstone; overlain conformably and locally unconformably by Coulters Sandstone.
Newlands Volcanics Ꝑha (0–2000+)	Porphyritic dacitic and rhyolitic ignimbrite and lava; minor feldspathic/lithic (volcaniclastic, tuffaceous) arenite, quartz arenite, micaceous arenite, siltstone, shale, mudstone, bedded tuff, ashstone, agglomerate, quartzite. Ignimbrite and lava: pink to dark grey and purplish grey where fresh, but generally lateritised and kaolinitic or sericitic; typically with abundant phenocrysts of elongate tabular plagioclase (now albite) up to 5 mm long ± quartz (partly resorbed) ± K-feldspar (partly resorbed, rare) and small mafic clots; commonly cleaved, foliated, or with platy joining parallel to igneous flow-banding or eutaxitic layering. Arenite: similar to that of Yeeradgi Sandstone. Bedded tuff: commonly grey or pink; medium to fine-grained; medium to thin-bedded; some graded bedding.	Conformable on and probably interfingers with Yeeradgi Sandstone, also conformable on Unimbra Sandstone in far SE; overlain conformably or disconformably by Coulters Sandstone. Intruded by granophyre.

TABLE 1. (continued)

Unit and map symbol (thickness in metres)	*Lithology*	*Relationships*
Yeeradgi Sandstone Ꝑhd (0–800)	Feldspathic/lithic arenite, micaceous arenite, siltstone, shale, minor felsic volcanics, greywacke. Arenite: buff, pink, grey, purplish, and iron-stained; friable to less commonly silicified; mostly medium to fine-grained, thin to medium-bedded, and cross-bedded; variably volcaniclastic/tuffaceous; possibly calcareous in places; ripple marks and bedding planes with siltstone/mudstone pellets common. Siltstone and shale: more common in upper part than lower part of formation; pale to dark grey or purplish; thin-bedded to laminated; micaceous; calcareous and carbonaceous locally; commonly cleaved/phyllitic. Felsic volcanics: include lava flows, bedded medium to fine-grained micaceous tuff, and cherty ashstone.	Conformable on Unimbra Sandstone, overlain conformably by and probably interfingers with Arabulja Volcanics and Newlands Volcanics; also overlain conformably and locally unconformably by Coulters Sandstone. Intruded by granophyre.
Unimbra Sandstone Ꝑhs (100–1500)	Feldspathic/lithic arenite and quartz arenite, commonly pebbly; minor conglomerate, micaceous greywacke and siltstone, felsic lava and pyroclastics. Arenite: white, pale grey, pink, or iron-stained; silicified to friable, with sparse to abundant clayey or sericitic matrix; variably feldspathic and/or lithic (partly volcaniclastic?); mainly medium to coarse-grained, medium-bedded, poorly to moderately well sorted and cross-bedded; commonly contains subangular to rounded clasts up to pebble size of vein quartz and also chert, jasper, fine-grained arenite, shale, quartz–tourmaline rock, and felsic volcanics, but non-pebbly in SE; ripple marks and bedding planes with grit or siltstone/mudstone pellets common; cleaved in places.	Unconformable on Warramunga Group; conformable/disconformable on Epenarra Volcanics, Edmirringee Volcanics, Kurinelli Sandstone, Taragan Sandstone, Treasure Volcanics, Mia Mia Volcanics; locally also overlies Kurinelli Sandstone and Treasure Volcanics with angular unconformity; also interfingers with Epenarra Volcanics and Treasure Volcanics; overlain conformably by Yeeradgi Sandstone and in far SE by Newlands Volcanics. Intruded by granophyre, dolerite/gabbro, and Devils Marbles Granite.
OORADIDGEE SUBGROUP Mia Mia Volcanics Ꝑhm (2000+)	Felsic tuff and lava; subordinate feldspathic/lithic arenite, quartz arenite; rare volcaniclastic arenite. Volcanics invariably much altered; generally with small phenocrysts of alkali feldspar + pseudomorphed mafic minerals ± quartz. Tuff: shades of grey, pink, maroon, purple and green; massive (ignimbrite?) to less commonly thinly bedded; commonly phyllitic or schistose; typically consists mainly of fine-grained muscovite/sericite, greenish brown biotite and/or chlorite, and quartz. Arenite: pale greyish to pinkish, or iron-stained; generally silicified and locally glassy; cross-bedding common, ripple marks less common.	Base not seen. Overlain conformably or disconformably by Unimbra Sandstone. Intruded by unnamed granite and discordant veins of pegmatite and greisen.
Treasure Volcanics Ꝑht (0–1800+)	Rhyolitic to dacitic lava, ignimbrite (in southeast of province), and minor bedded tuff, agglomerate and ashstone; interbanded quartz arenite, lithic/feldspathic arenite, volcaniclastic arenite, and basaltic lava. Felsic lava and ignimbrite: shades of grey, pink, maroon, purple, and brown; intensely weathered (lateritised) in many places; generally with small phenocrysts of plagioclase (now albite but originally more calcic, or pseudomorphed) ± partly resorbed quartz; locally schistose. Felsic lava in Hatches Creek tungsten field is highly altered, hornfelsic and apparently non-porphyritic, and consists of fine-grained biotite and/or chlorite, subordinate quartz and muscovite, ± porphyroblasts of muscovite and/or tourmaline. Bedded tuff: purple to maroon; friable; fine to coarse-grained; laminated to thin-bedded; commonly micaceous. Basaltic lava: confined to SW HATCHES CREEK REGION, remnant clinopyroxene and pseudomorphs after olivine present in some samples. Arenite: pale greyish or pinkish or iron-stained; friable to silicified; fine to coarse-grained; mainly medium-bedded; well to poorly sorted; generally cross-bedded; pebbles (mainly vein quartz), ripple marks, bedding planes with siltstone/mudstone pellets, and mudcracks present in places.	Conformable on and interfingers with Taragan Sandstone; also conformable on Kurinelli Sandstone; overlain conformably and unconformably by, and also interfingers with, Unimbra Sandstone. Intruded by granophyre and dolerite/gabbro.

TABLE 1. (continued)

Unit and map symbol (thickness in metres)	*Lithology*	*Relationships*
Taragan Sandstone Ᵽho (0–1000+)	Feldspathic/lithic arenite, quartz arenite, pebbly arenite, conglomerate; minor siltstone, mudstone, altered felsic lava. Arenite: pale pink, grey or white; silicified to friable; mainly medium to thick bedded and medium to coarse-grained; commonly poorly sorted, with sparse to abundant pebbles; cross-bedding very common, ripple marks common. Conglomerate: thick-bedded, with subangular to subrounded pebbles and locally cobbles and boulders in arenite matrix. Pebbles and larger clasts: mainly vein quartz; subordinate red, black, greenish or greyish chert; minor grey and pink quartz arenite, feldspathic arenite, and quartzite; also quartz–hematite rock, quartz–tourmaline rock, felsic volcanics. Siltstone and mudstone: grey, brown, or white; friable to silicified; thin-bedded to laminated; commonly micaceous; possibly calcareous in places.	Conformable and locally unconformable on, also interfingers with, Kurinelli Sandstone; overlain conformably by and interfingers with Treasure Volcanics; also overlain conformably/disconformably by Unimbra Sandstone. Intruded by granophyre, dolerite/gabbro, Devils Marbles Granite, unnamed granite.
Edmirringee Volcanics Ᵽhg (0–2500)	Basaltic lava; minor volcaniclastic arenite and siltstone; felsic lava. Basaltic lava: dark grey or greenish grey; amygdaloidal to massive; mainly non-porphyritic; locally schistose in Skinner Anticline; possible pillows at one locality (GR MS876790, KURUNDI REGION); typically consists of plagioclase laths (now mainly albite) + clinopyroxene (generally pseudomorphed by actinolitic amphibole or chlorite) ± pseudomorphed olivine + opaque minerals (commonly magnetite) + interstitial quartz + secondary epidote, sphene and/or chlorite; pumpellyite and prehnite present in KURUNDI REGION near GR MS830250; sulphides present locally; amygdale minerals mainly quartz and epidote, but also include chlorite, actinolite, albite, K-feldspar, calcite, chalcopyrite, pyrite, and galena. Arenite and siltstone: consist largely of basaltic lava clasts; commonly epidotic. Felsic lava: similar to that of, and probably comagmatic with, felsic lava of Epenarra Volcanics.	Conformable on and interfingers with Epenarra Volcanics; overlain conformably by and interfingers with Kurinelli Sandstone; overlain conformably and/or disconformably by Unimbra Sandstone.
Kurinelli Sandstone Ᵽhk (0–2600)	Feldspathic/lithic arenite, quartz arenite, micaceous and non-micaceous siltstone; minor felsic and mafic lava and tuff, mudstone, claystone, shale, slate and schist. Arenite: white, pale grey, greenish grey, pink, and brown; thin-bedded (especially near base) to medium and thick-bedded; mostly medium-grained and well sorted, but gritty and pebbly in places; silicified to friable; weakly calcareous in a few places; cross-bedding common; ripple marks and bedding planes with siltstone pellets present locally.	Conformable on Epenarra Volcanics, Edmirringee Volcanics, and Rooneys Formation; overlain conformably by Taragan Sandstone and Treasure Volcanics, and interfingers with all these formations; overlain conformably and unconformably by Unimbra Sandstone. Intruded by granophyre, dolerite/gabbro, Devils Marbles and unnamed granite.
Ᵽhk$_c$	Lithic arenite, quartz arenite, pebbly arenite, conglomerate.	Conformable lens within Kurinelli Sandstone.
Warnes Sandstone Member Ᵽhk$_w$ (0–500)	Quartz arenite and feldspathic/lithic arenite; typically massive, but bedding apparent in a few places; patchily silicified; bleached to iron-stained; poorly sorted; medium to coarse-grained, with scattered grit and pebbles of vein quartz common.	Conformable lenses within Kurinelli Sandstone. Intruded by granophyre and dolerite/gabbro sills.
Endurance Sandstone Member Ᵽhk$_d$ (0–500)	Thinly interbedded fine-grained micaceous greywacke and siltstone, commonly showing graded bedding; minor bands of feldspathic/quartz arenite.	Conformable lens within Kurinelli Sandstone.

TABLE 1. (continued)

Unit and map symbol (thickness in metres)	*Lithology*	*Relationships*
Rooneys Formation Ᵽhn (0–1200+)	Greywacke, siltstone, feldspathic/lithic arenite; minor felsic porphyry (possibly intrusive) in southeast. Clastic rocks: medium to fine-grained; mainly grey to iron-stained, and thin-bedded to laminated; variably micaceous; cross-bedding moderately common; rare ripple marks; locally calcareous; become increasingly schistose eastwards, both in the north and south.	Conformable on and interfingers with Epenarra Volcanics in north; base not exposed in south; overlain by and interfingers with Kurinelli Sandstone. Intruded by granophyre, dolerite/gabbro, Elkedra Granite, and unnamed granitic rocks.
Epenarra Volcanics Ᵽhr (0–3000+)	Felsic lava, ignimbrite, lapilli tuff, bedded sandy tuff, agglomerate, breccia, ashstone; volcaniclastic arenite, conglomerate and siltstone; quartzose arenite; conglomerate; minor altered mafic? lava. Felsic lava and ignimbrite: invariably altered; pinkish, purplish, greyish, or reddish brown (iron-stained); with phenocrysts of feldspar (generally pseudomorphed) + quartz + pseudomorphs after ferromagnesian minerals (mainly biotite?) and microphenocrysts of apatite and opaque oxide in very fine-grained iron-stained siliceous or sericitic groundmass; phyllitic to schistose in east. Arenite: white, pink, purple, maroon, and reddish brown; ranges from quartzose, especially near top of formation, to richly volcaniclastic, silicified to friable, well-sorted to poorly sorted, and thin to thick-bedded; sparse to abundant clayey sericitic matrix; some flaggy micaceous beds; cross-bedding common, ripple marks present locally. Mafic? lava: reddish to purplish brown, non-porphyritic, amygdaloidal, much altered; forms flow a few metres thick. Ashstone: commonly pale greenish, thin-bedded to laminated, cherty. Conglomerate: with clasts of penecontemporaneous felsic volcanic rocks and vein quartz, and quartzitic rocks derived from 'basement'.	Unconformable on Warramunga Group; may also overlie intrusive feldspar porphyry and unnamed granite; overlain by and interfingers laterally with Rooneys Formation, Edmirringee Volcanics, Kurinelli Sandstone; overlain conformably/disconformably by, and also interfingers, with Unimbra Sandstone. Intruded by granophyre.
WARRAMUNGA GROUP Ᵽw (1000+) Ᵽw$_{v}$	Interbedded greywacke, siltstone and shale; lithic arenite; subordinate felsic volcanics, chert, jaspilite. Porphyritic felsic volcanics. Greywacke and lithic arenite: medium to thin-bedded; medium to fine-grained; with angular to subangular detrital grains; show graded bedding, small-scale cross-bedding, broad trough bedding, slump bedding; weakly cleaved in places; commonly with abundant small flakes of metamorphic white mica and greenish brown biotite; may be largely volcaniclastic. Siltstone and shale: thin-bedded to laminated, micaceous and non-micaceous, commonly cleaved; with small flakes of metamorphic white mica and greenish biotite. Porphyritic volcanics: massive lava, brecciated lava and tuff; commonly cleaved; typically with abundant phenocrysts of quartz (partly resorbed), sodic plagioclase (commonly pseudomorphed), biotite (generally pseudomorphed), and less commonly microcline, hornblende (pseudomorphed) and allanite in fine-grained, groundmass of quartz, alkali feldspar and metamorphic greenish biotite, white mica, epidote, and chlorite; cross-cutting quartz and epidote veinlets common. Some lavas have perlitic textures indicative of altered glass. Chert and jaspilite: form bands about 1 m thick, with individual beds generally less than 3 cm thick; commonly show tight minor folds attributed to post-depositional slumping.	Base not exposed, stratigraphic top not identified. Overlain unconformably by Epenarra Volcanics, and Unimbra Sandstone of Hatches Creek Group; also by Cambrian strata and Mesozoic? sandstone. Intruded by Hill of Leaders Granite, unnamed granite, and probably dolerite.

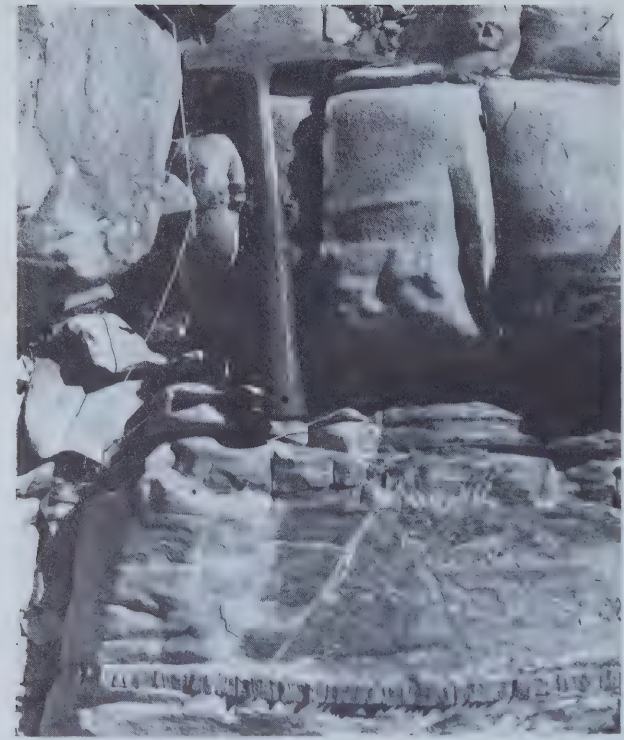


Fig. 10. Graded-bedded greywacke of the Warramunga Group, DEVILS MARBLES REGION (at GR MT297690). S. Wyche (M2697/15)

appear to be massive to partly fragmented lava flows (Fig. 11) and minor tuff beds.

The Warramunga Group was named by Ivanac (1954) and is formally defined in Dodson & Gardener (1978). No constituent formations have been distinguished and no stratigraphic sequence has been established within the Group in the Davenport province. Its thickness here, thought to be

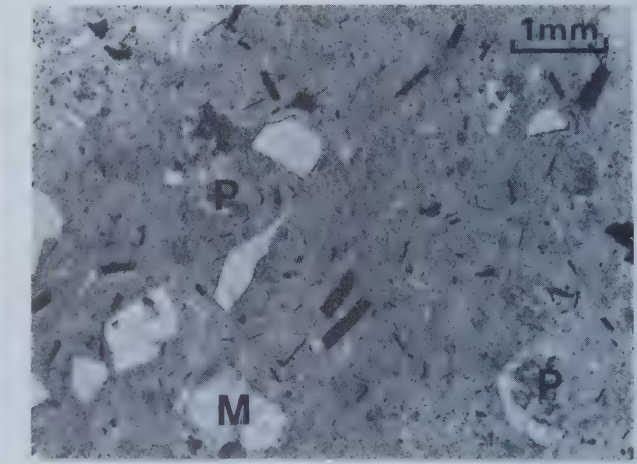


Fig. 11. Photomicrograph of felsic lava, Warramunga Group (sample No. 83110058B; from GR MT708645, KURUNDI REGION). Phenocrysts of partly resorbed quartz (white), sodic plagioclase (P), microcline (M), and biotite (pseudomorphed by opague oxide) are set in devitrified glass. (M2766/5)

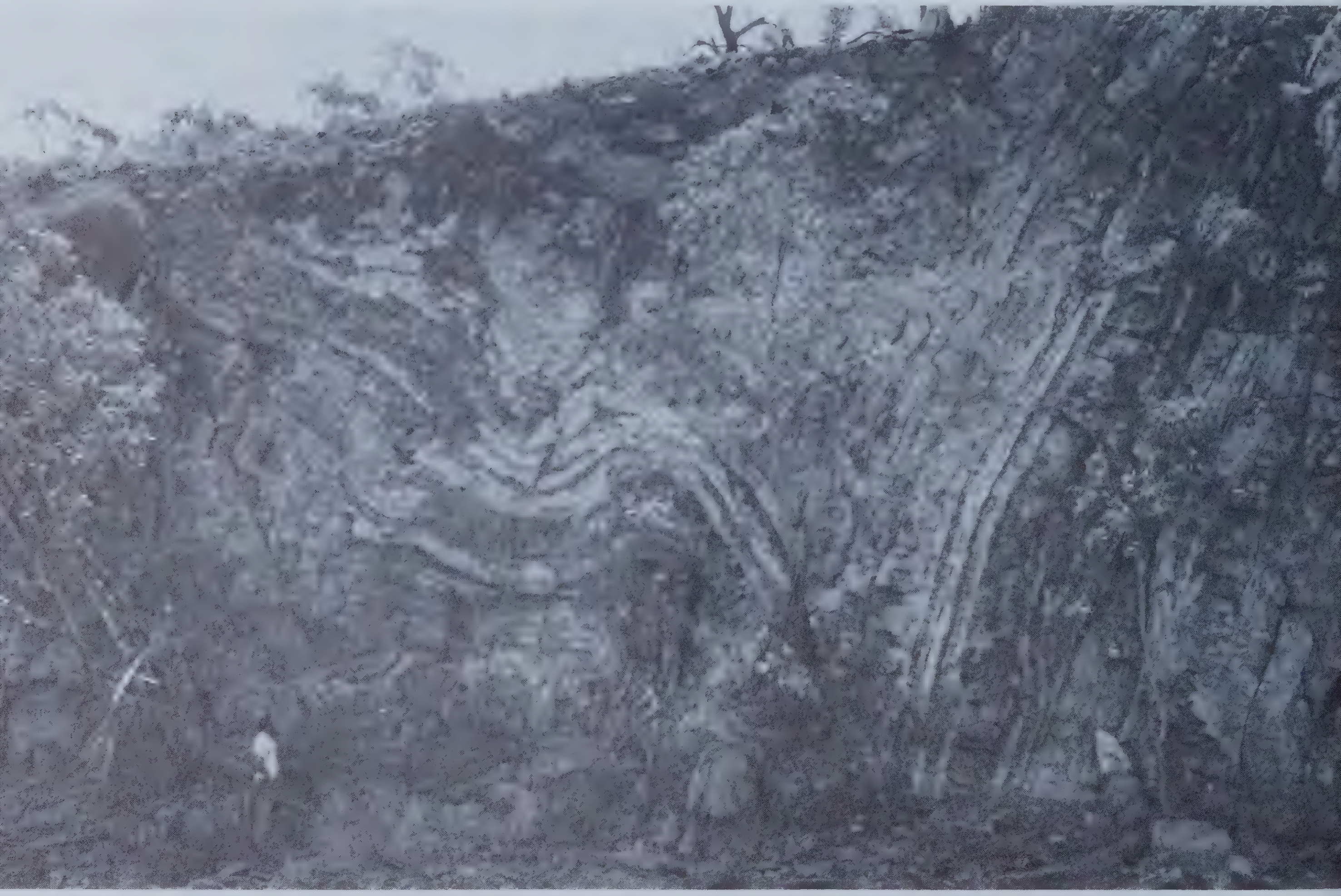


Fig. 12. Fold in the Warramunga Group, Turkey Creek, DEVILS MARBLES REGION (at GR MT352783). (M2543/OA)

in the order of several thousand metres, has not been determined because the stratigraphic top and base of the group have not been identified, no marker beds have been recognised, exposures are widely scattered, and bedding is complexly folded (Fig. 12). A U–Pb zircon age of about 1870 Ma was determined on felsic volcanics interlayered with turbiditic rocks in the Warramunga Group north of Tennant Creek by Black (1984), and a similar zircon age has been obtained for two samples of felsic volcanics from the group in the northern part of the Davenport province (Blake & Page, in press).

The Warramunga Group was folded, intruded by Hill of Leaders Granite, unnamed granite, and unnamed feldspar porphyry, and subjected to erosion, before it was overlain unconformably by the Hatches Creek Group. The folds (e.g. Fig. 12) typically have axial angles of around 90°, wave lengths of one kilometre or less, steeply dipping axial surfaces, and, especially in pelitic rocks, an associated axial surface cleavage.

A marked angular unconformity between the Warramunga Group and overlying Hatches Creek Group is well exposed at several localities along the flanks of the Gilbert Anticline and the east side of the Murchison Syncline in DEVILS MARBLES REGION (e.g., Fig. 13) and along the north side of the McLaren Syncline in KURUNDI REGION.

The presence of fine-grained metamorphic greenish biotite, white mica, and epidote in felsic volcanics, and white mica and less commonly biotite in greywacke and siltstone of the Warramunga Group in northern KURUNDI REGION and northern DEVILS MARBLES REGION indicate regional metamorphism to middle or upper greenschist facies. This metamorphism may be related to the pre-Hatches Group folding, or to the later deformation that also affected the Hatches Creek Group.

The prevalence of interbedded greywacke, much of which shows graded bedding, siltstone, and shale indicates that most of the Warramunga Group may have been laid down by turbidity currents. The wide distribution and lithology of the group indicate that deposition took place in an extensive basin, probably in moderately deep water, and was accompanied by felsic volcanism which presumably was subaqueous. Much of the detritus in the sediments may be penecontemporaneous volcanic material.

Near Tennant Creek to the north, the Warramunga Group is host to economically important gold, copper, and bismuth deposits (e.g., Ivanac, 1954; Large, 1975). However, in the

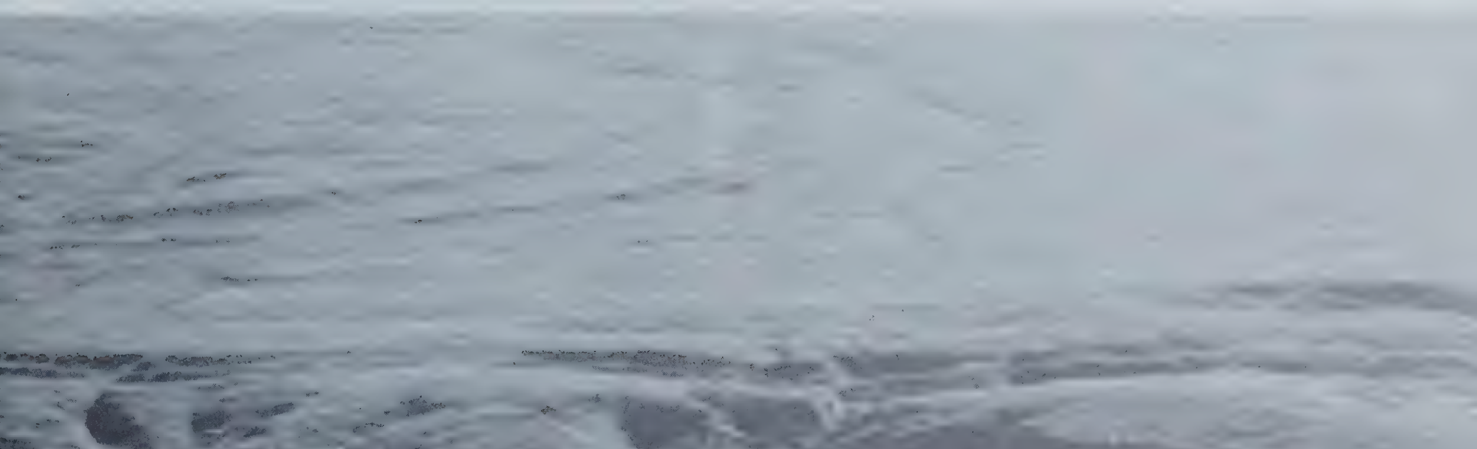


Fig. 13. Aerial view looking northwards across the Gilbert Anticline to the northwesterly plunging Murchison Syncline; part of the Murchison Range in northern DEVILS MARBLES REGION. The unconformity between the Warramunga Group, forming the hills in the foreground, and the Hatches Creek Group in the background is well exposed along the prominent cliff face in the middle distance. The maximum relief in the area shown is close to 100 m. S. Wyche (M2695/18A)

Davenport province only two small mineral deposits are known within the group. One is in DEVILS MARBLES REGION (at GR MT267559), where gold is associated with altered sulphides in weathered and largely concealed sedimentary and volcanic rocks. The other is at Woodenjerrie mine, HATCHES CREEK REGION (GR NT279369); here, quartz–hematite veins with wolframite and pyrite cut greywacke and siltstone.

The felsic volcanics of the Warramunga Group are similar in age, and also chemical composition, to the Leichhardt Volcanics (cover sequence 1) of the Mount Isa Inlier to the east (Blake & others, 1984; Blake, 1987), and possibly also to the felsic volcanics in the Mount Winnecke Formation of The Granites-Tanami province (Blake & others, 1979) to the west. Other possible correlatives of the Warramunga Group include Division 2 rocks of the Arunta Inlier to the southwest (Stewart & others, 1984); and the Tanami Complex of The Granites-Tanami region (Black & others, 1979) to the east (see Fig. 27).

HATCHES CREEK GROUP

Introduction

(DHB)

The Hatches Creek Group is a folded sequence at least 10 000 m thick of shallow-water sedimentary rocks and interlayered felsic and mafic volcanics cropping out extensively within the Davenport province. The sedimentary rocks include ridge-forming silicified quartz-rich arenite and subordinate conglomerate and recessive friable arenite, siltstone, mudstone, shale, carbonates, and minor possible evaporites. The volcanics are represented by recessive lavas (some of which were previously mapped as intrusives) and pyroclastics, and probably resulted from mainly subaerial eruptions. The group is intruded by felsic and mafic sills probably cogenetic and contemporaneous with the volcanics, and also by much younger granite plutons which postdate folding. Major unconformities separate the group from the underlying Warramunga Group and overlying Cambrian strata.

Sullivan (1953a) and Hossfeld (1954) were the first to use the name Hatches Creek Group. This name was retained by Smith & others (1961) and Ryan (1961), and has been followed in subsequent publications. As a result of the joint BMR/NTGS 1981–83 survey, the group has been formally subdivided into three subgroups, twenty formations, and two members (Table 1); these are defined by Blake & others (1984a).

The arenites of the Hatches Creek Group range from fine to coarse-grained and are well to poorly sorted. Beds of pebbly arenite and conglomerate are common in some units (e.g., Figs 21, 23). The arenites consist largely of detrital quartz derived from outside the Davenport province, and variable amounts of feldspar (mostly altered), lithic grains, mica, and clayey or sericitic material, of which at least some is locally derived volcanic detritus. Individual beds are mostly between 20 cm and 3 m thick. Siltstone and finer-grained sedimentary rocks are generally more thinly bedded. Deposition in fluvial to shallow-marine environments is indicated by widespread trough and planar cross-bedding, current and wave ripples, bedding planes with mudstone and siltstone pellets, stromatolitic carbonates in one formation, and rare mudcracks, halite casts, and gypsum moulds. The presence in many arenite beds of well-rounded to subangular pebbles, feldspar grains, clay, and prolapsed or recumbent-fold cross-bedding of the type described by Allen & Banks (1972) is indicative of rapid sedimentation.

The felsic volcanics of the Hatches Creek Group include tabular to lensoid lava flows up to 100 m or more thick, extensive ignimbrites, and subordinate bedded tuff, ashstone, agglomerate, and volcanic breccia. They range in composition from dacitic (63–70% SiO_2) to rhyolitic (more than 70% SiO_2). Many of the lavas have a platy jointing parallel to the flow base in their lower parts, contorted flow-banding in their upper parts, and autobrecciated margins. Some have fissured tops infilled with arenite. Ignimbrites generally contain lithic fragments and broken crystals, and in many cases have preserved eutaxitic textures. In a few places, mainly in landslip scars, welded lower parts of ignimbrite flows can be seen grading up into non-welded friable altered tuff. Bedded and massive tuffs are commonly cleaved (e.g., Fig. 14). The lavas and ignimbrites typically have phenocrysts less than 5 mm across of albite (replacing more calcic plagioclase), ferromagnesian minerals (invariably pseudomorphed) and, especially in rhyolite, partly resorbed quartz (Fig. 15). These are set in a very fine-grained and commonly iron-stained groundmass of quartz, alkali feldspar, opaque granules, and variable amounts of secondary chlorite, greenish brown biotite, epidote, white mica, and/or calcite. The groundmass typically shows spherulitic devitrification textures or snowflake recrystallisation textures. Small highly irregular (rather than almond-shaped) amygdales are present in many lava flows.

Mafic volcanics are represented mainly by tabular flows of amygdaloidal basaltic lava. Many of the flows have autobrecciated margins, with angular blocks of lava being enclosed in arenite or epidosite. Pillow structures have been found at only two localities, and most flows appear to have

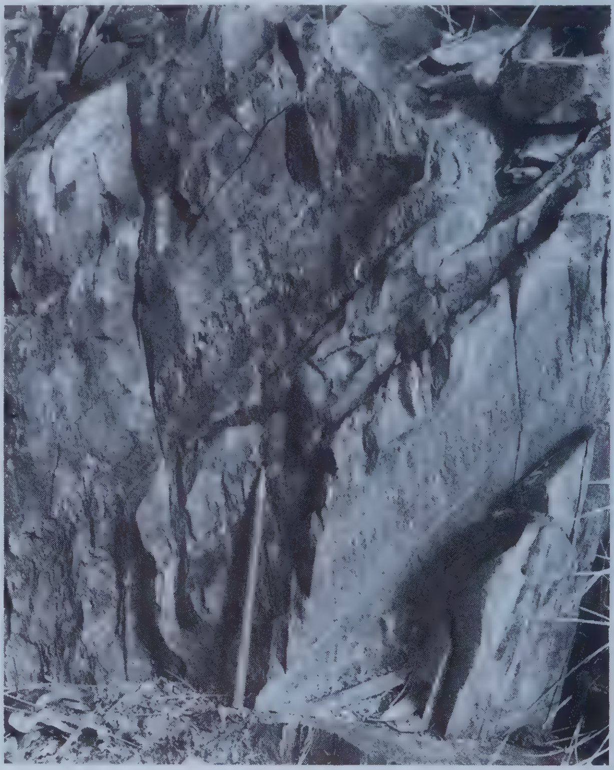


Fig. 14. Cleaved bedded tuff within the Newlands Volcanics, Hatches Creek Group, in ELKEDRA REGION (at GR NS155655). (M2523/11)

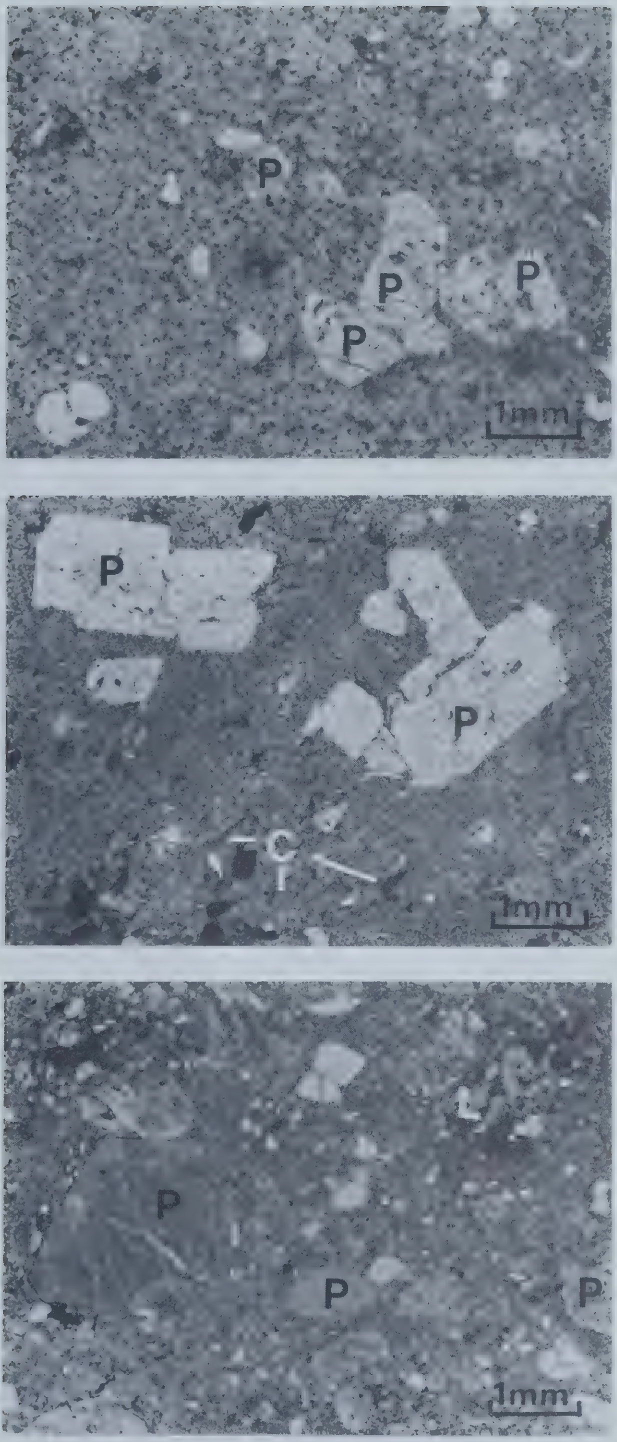


Fig. 15. Photomicrographs of three porphyritic felsic volcanic rocks from the Hatches Creek Group. In each rock the phenocrysts are enclosed in a very fine-grained quartzofeldspathic groundmass.
Top. Rhyolite lava (76% SiO_2) with phenocrysts of partly resorbed quartz (white), sodic plagioclase (P), and biotite? (pseudomorphed by opaque oxide) in a partly iron-stained groundmass (sample No. 81110641, Treasure Volcanics, from GR NS098985, HATCHES CREEK REGION). (M2766/1)
Middle. Dacitic lava (66.1% SiO_2), with euhedral phenocrysts of tabular sodic plagioclase (P), chlorite (C, pseudomorphing amphibole, pyroxene, or biotite), and opaque oxide (sample No. 82110053A, Newlands Volcanics, from GR NS311578, ELKEDRA REGION). (M2766/9)
Bottom. Rhyolitic ignimbrite with euhedral and fragmented phenocrysts of quartz (white) and sodic plagioclase (P), together with small lithic clasts (L) (sample No. 82110357, from GR NS452291, ELKEDRA REGION). (M2766/7)

been erupted subaerially. Typical lavas consist largely of altered plagioclase laths, clinopyroxene (generally pseudomorphed), opaque oxide, and secondary minerals such as albite, actinolitic amphibole, greenish brown biotite, chlorite, epidote, and quartz. Plagioclase phenocrysts are present in some lavas. There are also a few flows of altered trachyte with K-feldspar phenocrysts, and some mafic tuffs.

The distribution of felsic and mafic volcanic units of the Hatches Creek Group, together with inferred major eruptive centres, is shown in Fig. 16. The eruptive centres are taken to be located near (1) the thickest parts of the volcanic units; (2) coarse pyroclastic deposits; (3) sequences incorporating several felsic lavas (which are unlikely to have flowed far from their source); and (4) areas of intensely altered volcanic rocks.

The predominance of shallow-water sediments and subaerial volcanics in the Hatches Creek Group implies that deposition kept pace with region-wide subsidence. The amount of subsidence presumably exceeded 10 000 m, as the group is at least this thick throughout most of the Davenport province.

Stratigraphy
(DHB)

The oldest subgroup of the Hatches Creek Group, the *Ooradidgee Subgroup*, consists of seven partly interfingering formations of mainly fluvial sedimentary rocks and subaerial volcanics, whereas the seven formations of the overlying *Wauchope Subgroup* and the six formations of the younger *Hanlon Subgroup* are more regularly layered. The Wauchope Subgroup contains voluminous volcanics and probably both marine and fluvial sediments, unlike the Hanlon Subgroup, which is largely devoid of volcanics and may be entirely marine. The entire sequence is generally conformable, but there are a few local unconformities where beds have been folded and eroded before being overlain by succeeding units. Such unconformities may be attributed to slumping during syndepositional faulting and volcanism.

Details of the stratigraphy are given in Table 1.

Ooradidgee Subgroup

The basal formation of the Ooradidgee Subgroup in the north of the Davenport province is the *Epenarra Volcanics*, a unit composed mainly of felsic lavas and pyroclastics with interlayered sedimentary rocks which have variable amounts of volcaniclastic detritus (Figs 17, 18). The volcanic rocks are generally deeply weathered, and in places are also strongly cleaved (phyllitic to schistose), especially in the east. Where poorly exposed, they cannot always be easily distinguished from felsic volcanics in the Warramunga Group, or from unnamed intrusive feldspar porphyry. Marked lateral variations in thickness of the formation are due partly to deposition on an uneven surface of folded Warramunga Group rocks (Fig. 19), with a relief in places of perhaps several hundred metres and partly to the development of substantial volcanic edifices around which sediments of adjacent formations were deposited. The felsic volcanics were probably erupted from several separate volcanoes (Fig. 16), including one forming part of the Pingelly Block and another to the northwest. Both of these centres may have been active throughout Ooradidgee Subgroup time, as in places they are overlain apparently conformably by Unimbra Sandstone, the basal formation of the Wauchope Subgroup. The Epenarra Volcanics are overlapped to the southeast by Rooneys Formation and to the south and west by Edmirringee Volcanics and Kurinelli Sandstone.

The *Rooneys Formation* crops out in the southeast, where it is the oldest unit of the Hatches Creek Group exposed, and also in the northeast, where it overlaps onto the Epenarra Volcanics. In both outcrop areas the formation consists predominantly of thin-bedded arenite, greywacke, and siltstone which are overlain by, and probably also pass

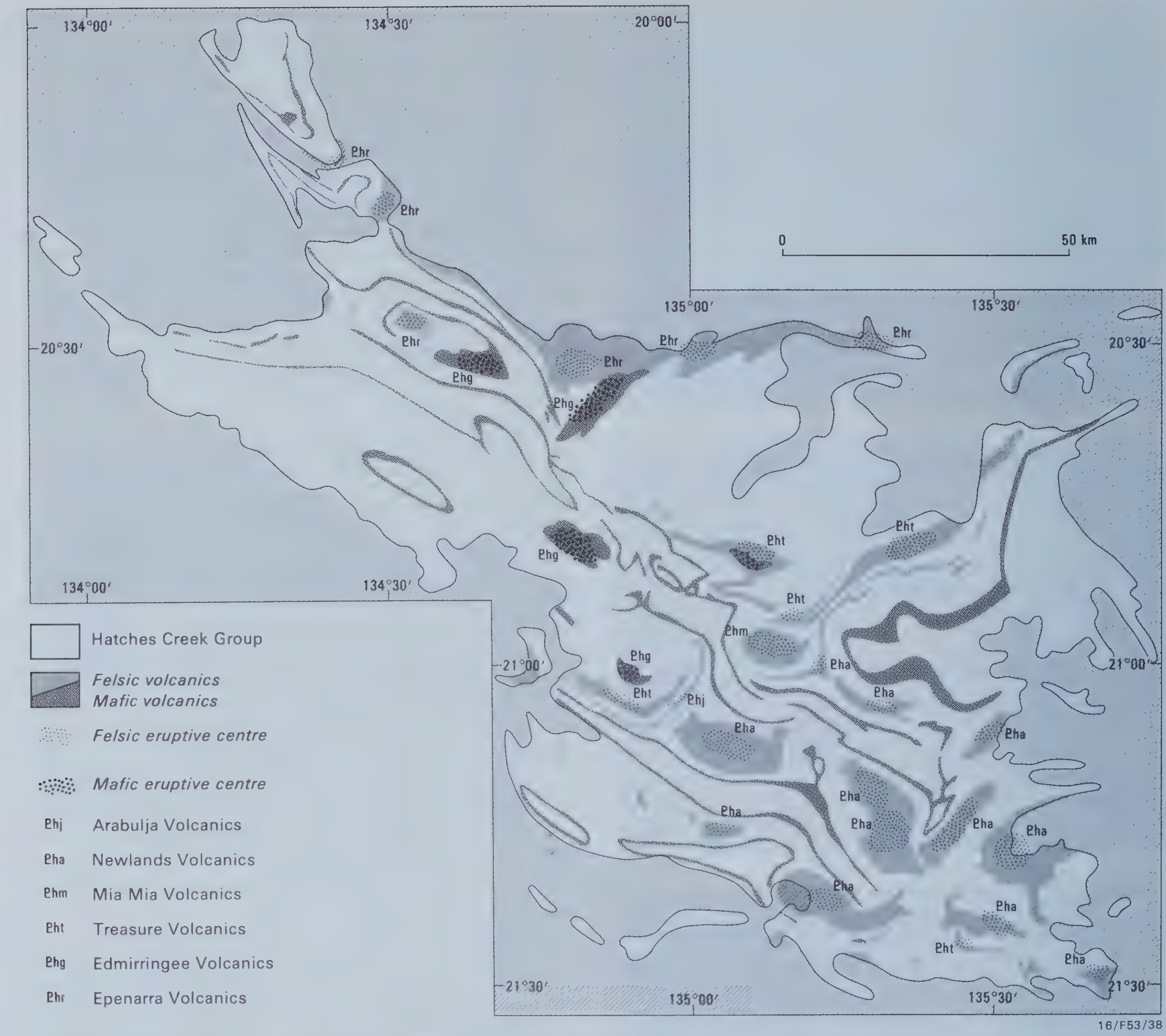


Fig. 16. Distribution of felsic and mafic volcanics of the Hatches Creek Group and inferred major eruptive centres.

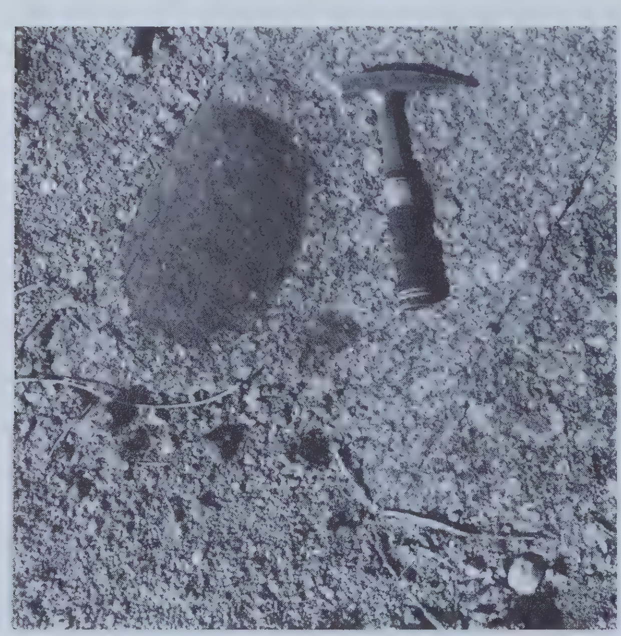


Fig. 17. Coarse pyroclastic rock within the Epenarra Volcanics, KURUNDI REGION (at GR MT480620). (M2536/2)

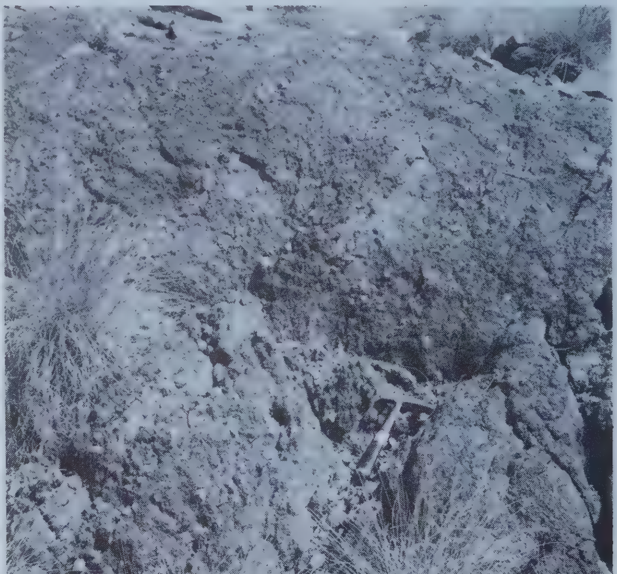


Fig. 18. Bedded coarse tuffaceous/volcaniclastic rocks, Epenarra Volcanics, DEVILS MARBLES REGION (at GR MT370600). (M2536/9)

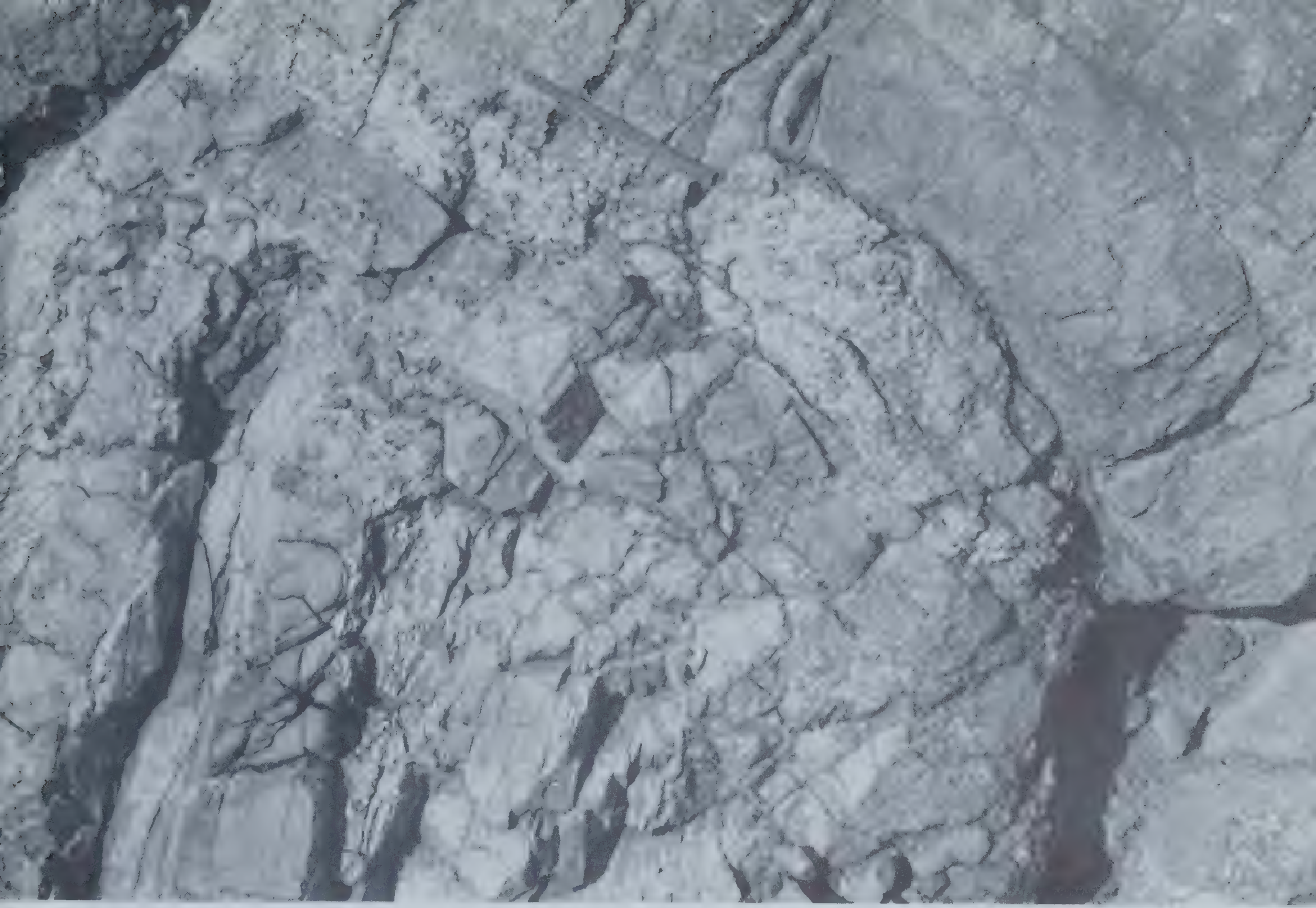


Fig. 19. Southwesterly dipping volcaniclastic beds at the base of the Epenarra Volcanics, unconformably overlying subvertical greywacke and siltstone of the Warramunga Group in KURUNDI REGION (at GR MT481621). (M2536/5)

laterally into, Kurinelli Sandstone. Near Kurinelli Outstation in HATCHES CREEK REGION, the Rooneys Formation and associated dolerite and gabbro sills are cut by auriferous quartz veins.

The *Kurinelli Sandstone*, the most widespread formation of the Ooradidgee Subgroup, consists mainly of ridge-forming silicified quartz, lithic, and feldspathic arenites and recessive friable beds, but also includes some interlayered felsic and mafic volcanics which may be contiguous with adjacent contemporaneous volcanic formations (Epenarra, Edmirringee, and Treasure Volcanics). Much of the lithic detritus and feldspar in the sedimentary rocks may be tuffaceous or volcaniclastic. Deposition took place during active volcanism, and the Kurinelli sediments overlapped, interfingered with, and in places probably overtopped volcanic edifices.

In a few places, the Kurinelli Sandstone has been deformed to schist, as in the Skinner Anticline, KURUNDI REGION, where it is taken to include a finely banded quartz–tourmaline rock in which the tourmaline shows a strongly preferred orientation parallel to the banding. This tourmaline-rich rock may represent either a chemical sediment or a hydrothermally altered rock (by concealed granite?), or highly deformed quartz–tourmaline veins.

Two named members have been distinguished within the Kurinelli Sandstone. One is the *Endurance Sandstone Member*, a recessive unit of possibly deltaic greywacke and siltstone that is exposed in southern HATCHES CREEK REGION. The other is the *Warnes Sandstone Member*, which forms knobbly, rather than smooth, ridges and is almost devoid of bedding—possibly because of earthquake shaking or large-scale slumping, or both, shortly after deposition. The Kurinelli Sandstone also includes an unnamed member, map unit Phk_c, which is a pebbly to conglomeratic arenite present at the top of the formation in KURUNDI REGION.

The Kurinelli Sandstone is cut by gold-bearing quartz veins in KURUNDI REGION and HATCHES CREEK REGION, and also by quartz veins with wolframite and minor scheelite, copper and bismuth minerals in the Hatches Creek tungsten field.

The predominantly basaltic *Edmirringee Volcanics* crop out in four areas in the central part of the Davenport province: in the cores of the Skinner Anticline, Kurundi Anticline, and Murray Downs Dome of the Wauchope Fold Belt, and in the Edmirringee Block. Lithologic differences indicate that each of these outcrop areas may represent a separate volcanic centre (Stewart & Blake, 1984, and 1986). Felsic lavas locally interfingering with basalt lavas of the formation may be related to the Epenarra Volcanics, which were being erupted at about the same time from volcanic centres to the north. Interlayered arenites belong to the Kurinelli Sandstone. Several occurrences of copper, lead, and silver are known within the Edmirringee Volcanics: copper and lead minerals are present in amygdales in basalt in the Kurundi Anticline and Murray Downs Dome, copper minerals have been found in basalt exposed in the Edmirringee Block, and small amounts of lead and silver have been obtained from galena-bearing quartz veins cutting basalt in the Murray Downs Dome (at the Silver Valley prospects, ELKEDRA REGION).

The *Taragan Sandstone* of the Ooradidgee Subgroup is confined to the central part of the Davenport province, where it generally overlies Kurinelli Sandstone and underlies Treasure Volcanics. Main rock types are ridge-forming pebbly arenite and conglomerate (Fig. 20), but in places the formation includes a band of recessive friable arenite, siltstone, and mudstone. Most of the pebbles in the formation may be derived from the Warramunga Group. In the Wauchope and Hatches Creek tungsten fields, the formation is cut by wolframite-bearing quartz veins.

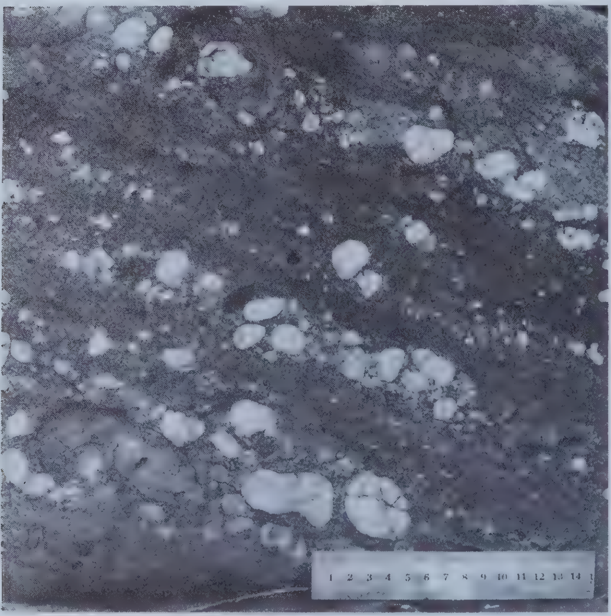


Fig. 20. Pebbly arenite, Taragan Sandstone, KURUNDI REGION (at GR MT900103). Almost all the pebbles are of white vein quartz. Scale is in centimetres. (M2524/32A)

The *Treasure Volcanics* crop out most extensively in the eastern central part of the Davenport province, but have also been mapped in the southeast. In the main outcrop area, rhyolitic and dacitic lavas are interlayered with generally subordinate ridge-forming arenites and, northwest of the Hatches Creek tungsten field, with recessive basaltic lavas. The volcanic rocks are considered to be largely, if not entirely, subaerial. Eruptive centres may be located near the Hatches Creek tungsten field (where the volcanics are highly altered), to the northwest (near the type section of the formation) and northeast in HATCHES CREEK REGION, and within the Murray Downs Dome farther west. An additional volcanic centre was active at the same time in the southeast of the province, where felsic ignimbrite (Fig. 21), tuff and agglomerate assigned to the Treasure Volcanics are exposed. Many of the arenites within the formation are indistinguishable lithologically from arenites in either the underlying Taragan Sandstone or in overlying Unimbra Sandstone of the Wauchope Subgroup. Like the Kurinelli and Taragan Sandstones, the Treasure Volcanics are cut by mineralised quartz veins in the Hatches Creek tungsten field.

The remaining formation of the Ooradidgee Subgroup, the *Mia Mia Volcanics*, is confined to the Mia Mia Dome southwest of the Hatches Creek tungsten field. Unlike the Treasure Volcanics, with which it is correlated, the Mia Mia Volcanics consist mainly of pyroclastic rocks, but it also includes some rhyolitic lava and bands and lenses of ridge-forming arenite. The pyroclastic rocks are invariably altered and cleaved.

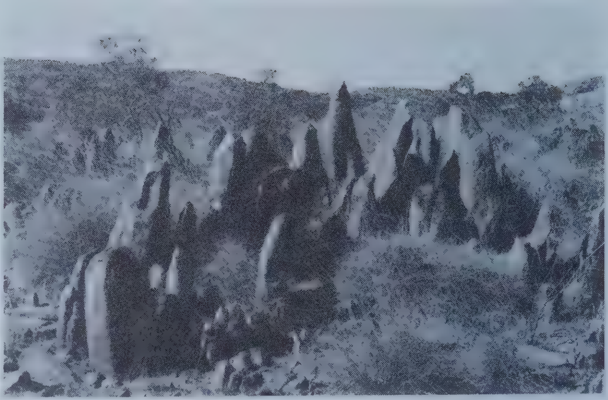


Fig. 21. Exposure of rhyolitic ignimbrite, Treasure Volcanics, in southeast ELKEDRA REGION (at GR NS450291).

Wauchope Subgroup

The basal unit of the Wauchope Subgroup, overlying and locally interfingering with formations of the Ooradidgee Subgroup, is the *Unimbra Sandstone.* This formation is the oldest of three major region-wide ridge-forming units within the Hatches Creek Group—the others being the Coulters Sandstone and Errolola Sandstone (Fig. 22). In the central and northern parts of the Davenport province, the Unimbra Sandstone is commonly pebbly to conglomeratic (Fig. 23), but pebbles are rare in the southeast. Layers and lenses of felsic volcanics are present locally. The formation ranges in thickness from less than 200 m, as near Unimbra Rockhole in southwest HATCHES CREEK REGION (Fig. 24), to at least 1500 m. The variations in thickness of the formation can be attributed partly to deposition on an uneven surface of Ooradidgee Subgroup volcanics and, in the far north, eroded Warramunga Group rocks, and partly to syndepositional faulting (see below).

The overlying *Yeeradgi Sandstone* is a less-resistant ridge-forming to recessive unit which generally has an appreciable volcaniclastic content probably derived from penecontemporaneous felsic volcanism. A small deposit of wolframite-bearing greisen occurs in the formation in DEVILS MARBLES REGION (at GR MT270284).

In the central and southern parts of the province, the Yeeradgi Sandstone is overlain by two correlative felsic volcanic formations, the Arabulja Volcanics in the west and the more widespread Newlands Volcanics to the east. The *Arabulja Volcanics* consist predominantly of two or more tabular lava flows which appear to be unusually extensive (at least 20 km long) relative to their thickness (less than 300 m) and may have been less viscous than typical felsic lavas. The flows contain equant feldspar phenocrysts up to 5 mm across and are invariably much altered. The *Newlands Volcanics* include both ignimbrite and lava flows. Although largely altered to clay or sericite (partly as a result of weathering), fresh volcanic rock is exposed locally, mainly as small smoothly rounded boulders on footslopes or low mounds. The typical rock type of the Newlands Volcanics is welded dacitic ignimbrite with abundant elongate feldspar phenocrysts about 5 mm long and irregular clots of fine-grained biotite. Friable non-welded ignimbrite is exposed in some landslip scars on steep slopes where the formation is overlain by Coulters Sandstone. Several overlapping eruptive centres may be present in ELKEDRA REGION (Fig. 16), where the Newlands Volcanics reach thicknesses of more than 2000 m. The volcanism was mostly, if not entirely, subaerial, and arenites within the volcanic piles are either fluvial or shallow marine. Some non-bedded quartzite present locally may represent silicified fumarolic deposits.

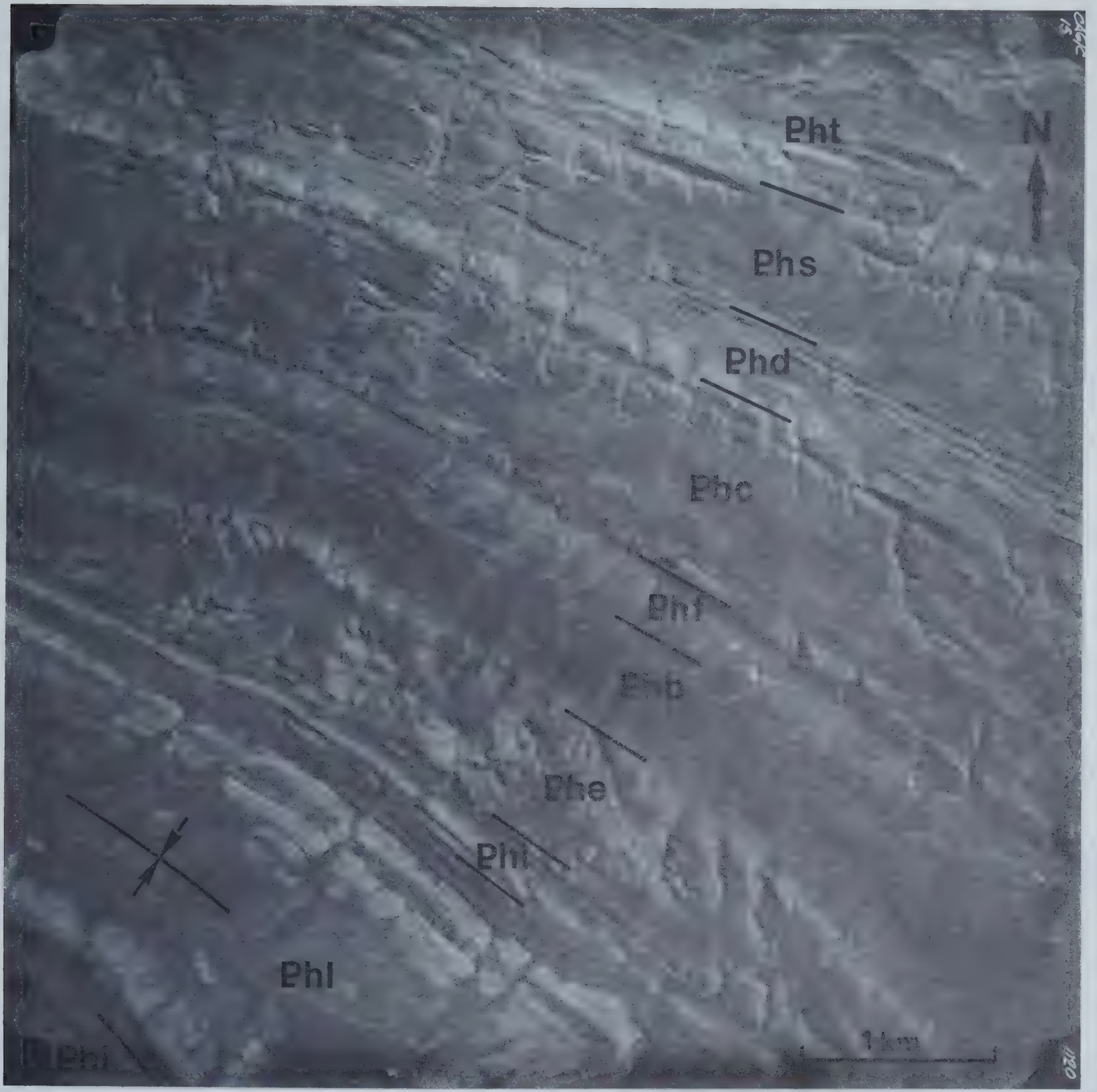


Fig. 22. Vertical aerial photograph showing the three major ridge-forming units of the Hatches Creek Group exposed on the northwestern limb of the Bonney Syncline in southwest HATCHES CREEK REGION and southeast KURUNDI REGION: Unimbra Sandstone (Ᵽhs), Coulters Sandstone (Ᵽhc), and Errolola Sandstone (Ᵽhe). Other formations shown are Treasure Volcanics (Ᵽht), Yeeradgi Sandstone (Ᵽhd), Frew River Formation (Ᵽhf), Kudinga Basalt (Ᵽhb), Alinjabon Sandstone (Ᵽhi), and Lennee Creek Formation (Ᵽhl). (Hatches, run 9, No. 1120, CAG/C15, 16.9.1980)

The *Coulters Sandstone*, the middle of the three major region-wide ridge-forming units, directly overlies Newlands Volcanics, Arabulja Volcanics and, in the northwest, Yeeradgi Sandstone. It consists mainly of resistant quartz arenite which in the southeast has an appreciable feldspathic or lithic content, but in parts of the province it also includes one or two narrow recessive bands, one in the middle and the other near the top of the formation. Both recessive bands are formed of friable arenite and siltstone, which may be tuffaceous or volcaniclastic, and the lower band also includes altered lava of probably basaltic composition. Although generally less than 1000 m thick, the Coulters Sandstone is apparently as much as 5000 m thick in central HATCHES CREEK REGION, possibly because of strike faulting or thrusting.

Much of the conformably overlying recessive *Frew River Formation* is concealed beneath Cainozoic alluvium and colluvium. The upper part of this sedimentary unit includes dolomitic and calcareous beds which in places are stromatolitic (Fig. 25) and in the far southeast are exposed as manganiferous and hematitic 'gossans'. The youngest formation of the Wauchope Subgroup, the *Kudinga Basalt*, is conformable on the Frew River Formation. It consists mainly of recessive tabular basaltic lava flows, but commonly includes two thin bands of ridge-forming arenite at or near its base (see Fig. 22). Small patches of calcrete are developed on many basalt exposures. Pillow lava (Fig. 26) has been found at only two localities, both in KURUNDI REGION, and most lavas are presumed to be subaerial. The flows were probably laid down on a region-wide fluvial plain. No eruptive sites have been

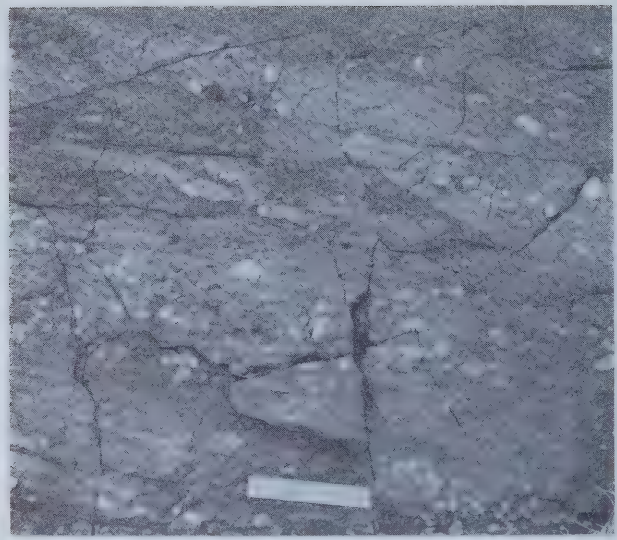


Fig. 23. Pebbly arenite in lower part of Unimbra Sandstone, KURINDI REGION (at GR MS855955). Scale is in centimetres. (M2455/8)

identified. The unit is a useful stratigraphic marker, as it enables the Coulters Sandstone to be readily distinguished from the lithologically and topographically similar Errolola Sandstone, the basal formation of the overlying Hanlon Subgroup. The Kudinga Basalt is cut by copper-bearing quartz veins at a prospect in HATCHES CREEK REGION (at GR NT377875), and it contains a radioactive phosphate rock at a locality in KURUNDI REGION (at GR MT535114).

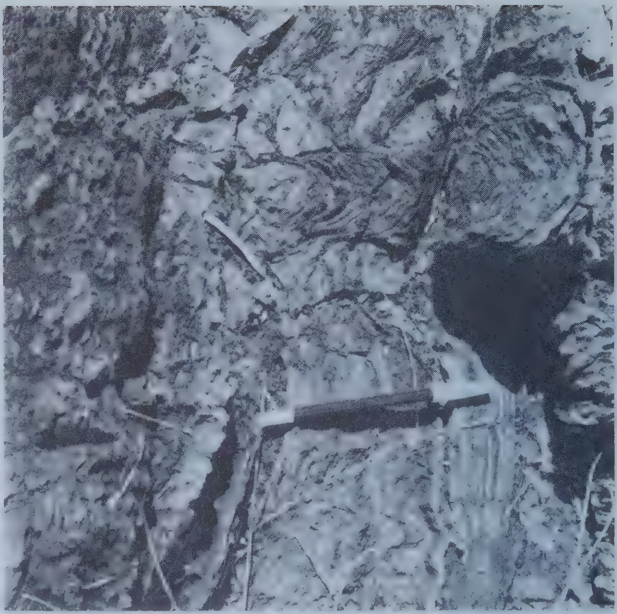


Fig. 25. Stromatolitic carbonates of the Frew River Formation in central ELKEDRA REGION (at GR NS394474). (M2543/11A)

Hanlon Subgroup

The *Errolola Sandstone* typically forms a single broad strike ridge (e.g., Fig. 22), but in the far southeast it is represented by two narrow ridges and an intervening thin recessive band. The formation marks the beginning of a

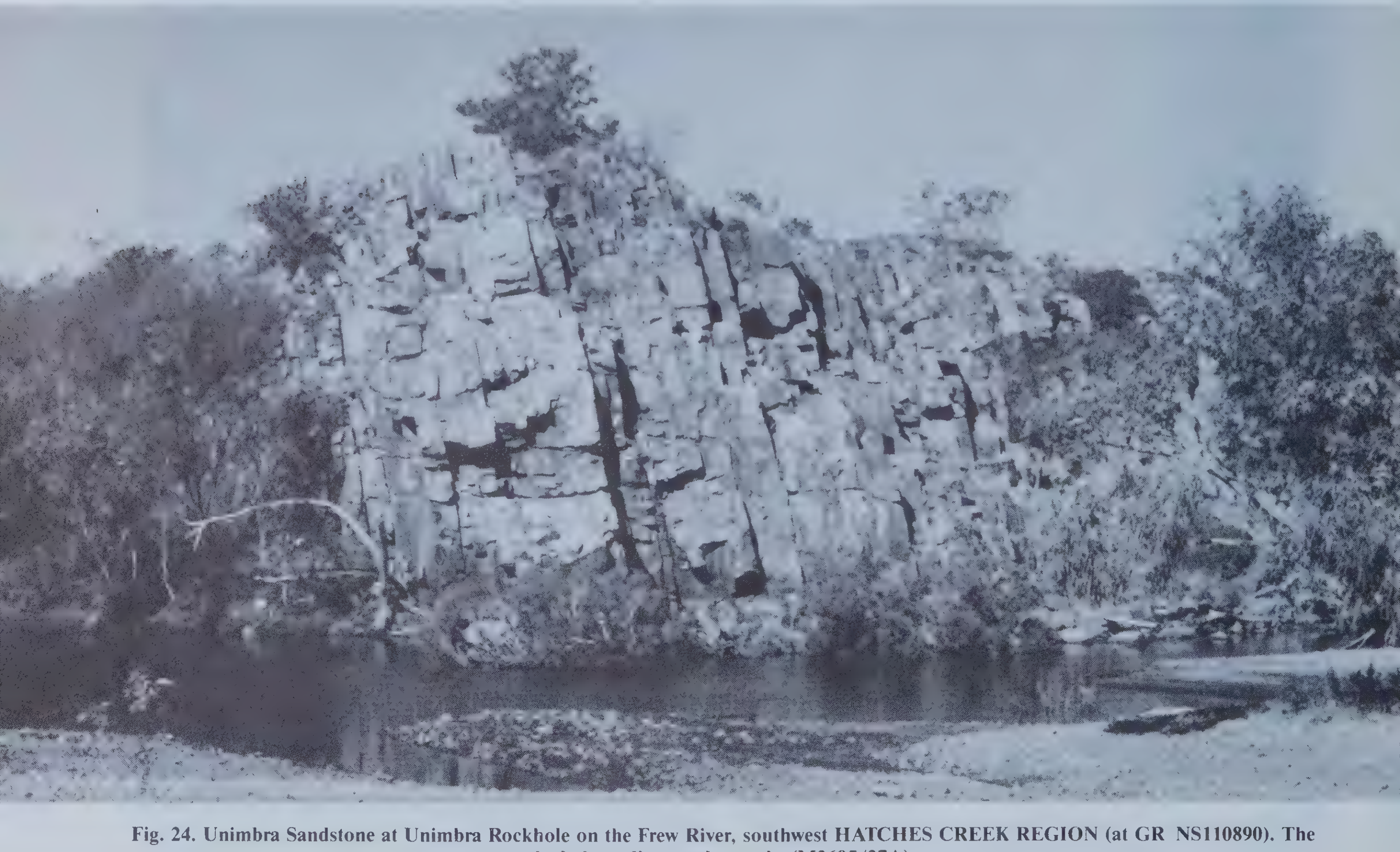


Fig. 24. Unimbra Sandstone at Unimbra Rockhole on the Frew River, southwest HATCHES CREEK REGION (at GR NS110890). The beds here dip steeply south. (M2695/27A)

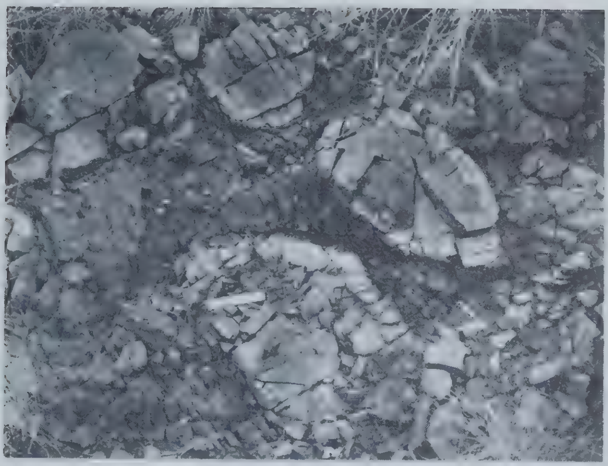


Fig. 26. Pillow lava in Kudinga Basalt, KURUNDI REGION (at GR MS910879). Pillows of basalt with pale chilled margins are enclosed in a basaltic schist matrix. (M2462/10)

marine transgression, and was probably deposited on intertidal flats and adjacent subtidal environments (see below). The overlying *Alinjabon Sandstone* consists of two or three bands of ridge-forming arenite alternating with recessive bands (as shown in Fig. 22), which in places include highly altered mafic lavas, the youngest volcanic rocks known in the Hatches Creek Group. Where three ridge-forming bands are present, the uppermost band, and underlying recessive band, may correlate with the basal part of the Lennee Creek Formation elsewhere.

The *Lennee Creek Formation* may have been deposited partly in deeper water than most other sediments of the Hatches Creek Group (see section on sedimentology). It generally forms gently undulating terrain, in places with calcrete and magnesite concretions on the surface, but narrow bands of low ridge-forming quartz arenite are present locally in the lower and middle parts of the formation. The succeeding *Canulgerra Sandstone* marks a return to shallow-marine, possibly intertidal, conditions. It crops out in the east of HATCHES CREEK REGION and in synclines to the west. Although the main rock type is quartz arenite, which forms low ridges, this formation also includes some bands of recessive siltstone and shale and rare conglomerate.

In eastern HATCHES CREEK REGION, the Canulgerra Sandstone is overlain by recessive sedimentary rocks of the largely concealed *Vaddingilla Formation*, which is overlain in turn by low ridge-forming *Yaddanilla Sandstone*, the youngest formation of the Hatches Creek Group in the Davenport province.

Age

Conventional U-Pb zircon data for two felsic volcanic rocks (both with 70% SiO_2) from the Ooradidgee Subgroup are reported by Blake & Page (in press). One sample, of porphyritic lava from the Epenarra Volcanics in the north of the Davenport province, is probably between 1820 and 1894 Ma old. An age of 1813 ± 5 Ma was obtained on the other sample, a porphyritic ignimbrite from the Treasure Volcanics in the southeast of the province. Interpretations of the zircon data are hampered by complexities due to inheritance and/or Pb loss, but Blake & Page (in press) conclude that the preferred age for the Ooradidgee Subgroup is 1810–1820 Ma.

A minimum age for the Hatches Creek Group is given by the Elkedra Granite, which was emplaced in the far southeast of the province after the Hatches Creek Group had been deformed. This granite has been dated by the Rb-Sr whole-rock method at about 1660 Ma — recalculation by Page (in Blake & Page, in press) of 1695 Ma age obtained by Riley and quoted by Compston & Arriens (1968).

Correlations

The Hatches Creek Group, as well as extending over the entire Davenport province, also crops out to the southwest, where it forms the Osborne and Crawford Ranges in the northwest of *Barrow Creek* (Smith & Milligan, 1964). All three subgroups are probably represented in these ranges (Wyche, personal communication, 1985). Farther to the southwest, probable correlatives of the Hatches Creek Group are represented by *Division 3* of the *Arunta Inlier* (Stewart & others, 1984). Possible correlatives northwest of the Arunta Inlier, in *The Granites-Tanami region*, are the *Mount Winnecke Formation, Supplejack Downs Sandstone,* and *Pargee Sandstone* (Blake, 1978; Blake & others, 1979).

In the *Tennant Creek Inlier* to the north of the Davenport province, Blake (1984) has shown that (1) the *Rising Sun Conglomerate* near Tennant Creek probably includes correlatives of both the Ooradidgee Subgroup (Epenarra Volcanics) and Wauchope Subgroup (Unimbra Sandstone); (2) some rocks north of Tennant Creek which have been included within the *Warramunga Group* are unconformable on this group and may be correlated with the Ooradidgee Subgroup; and (3) part of the overlying *Tomkinson Creek beds* can be correlated with the Wauchope and Hanlon Subgroups of the Hatches Creek Group. One of the formations within the Tomkinson Creek beds, the basaltic *Whittington Range Volcanics*, probably correlates with the Kudinga Basalt at the top of the Wauchope Subgroup. The Tomkinson Creek beds form part of the mid-Proterozoic North Australian Platform Cover of Plumb (1979a, 1979b), and are thought to include correlatives of the *McArthur Basin succession* (e.g., Plumb & others, 1981), part of which is equivalent to *cover sequence 3* (1670–1680 Ma) of the *Mount Isa Inlier* (Blake, 1987). Hence, the Tomkinson Creek beds appear to include two separate sequences, one 150 Ma younger than the other.

Possible correlations, summarised in Fig. 27, show that the Hatches Creek Group and equivalent units may once have covered a large part of central Australia.

Sedimentology

(IPS)

A reconnaissance sedimentological study of the Hatches Creek Group was undertaken in 1982 to identify depositional environments and to describe where possible provenance and diagenetic features. Most formations have been assessed on the examination of only a small number of sections or outcrops (Fig. 28). Where time permitted, complete stratigraphic sections of formations were measured, and palaeocurrent data were collected, mainly on foreset bedding. The palaeocurrent data were corrected for the effects of both plunge of fold axes and the dip of fold limbs.

A primary task in the environmental analysis was to distinguish between marine and non-marine facies. Of the many approaches commonly used in making this distinction the most reliable is biologic, as emphasised by Heckel (1972) and Johnson (1978). Where floral and faunal evidence is lacking, as in Proterozoic units such as the Hatches Creek Group, the presence of glauconite and of tidal sediments are perhaps the best indicators of marine rather than non-marine facies. If these are also lacking, a variety of stratigraphic and sedimentological criteria have to be applied instead. The main ones, summarised by Pettijohn & others (1973) in a series of tables, are petrology, texture, depositional structures, and internal organisation of sandstone bodies (size, shape and orientation, and lithologic associations). Of these criteria,

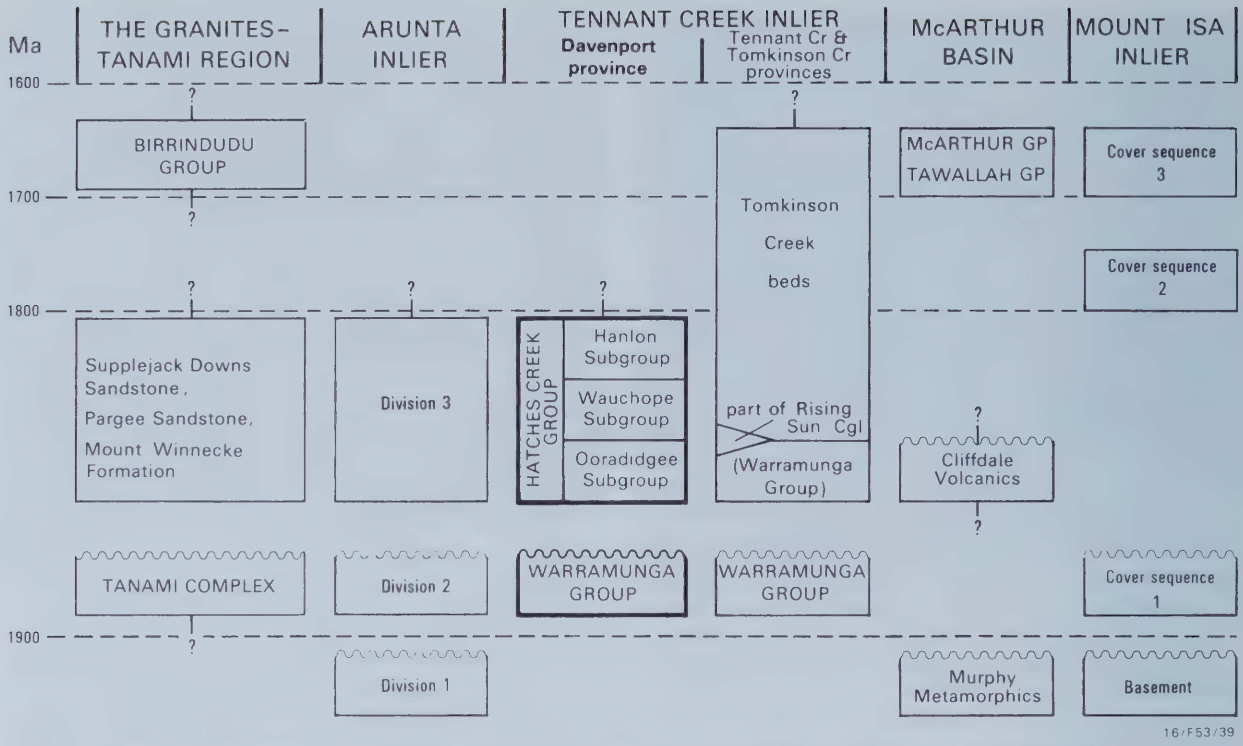


Fig. 27. Stratigraphic correlation chart for the Proterozoic of the Davenport province and nearby regions.

sedimentary structures and internal organisation currently receive the most attention, having been the focus of facies modelling over the past decade or so, and, together with the analysis of vertical profiles, may be sufficient to distinguish marine from non-marine deposits in the Hatches Creek Group.

It may be argued that unless glauconite or tidalites can be identified, the facies should only be described as subaqueous—i.e., marine *or* lacustrine. However, the vast extent and considerable thicknesses of the Hatches Creek Group and its correlatives are much more likely to result from the prolonged existence of epicontinental seas than of large lakes. While closures of seaways, leading to the development of temporary lakes or 'inland seas', cannot be discounted, the non-fluvial sedimentary units of the Hatches Creek Group (with the possible exception of the Rooneys Formation near the base of the sequence) are interpreted as marine.

Rooneys Formation

The Rooneys Formation was examined only in its type section in northeast HATCHES CREEK REGION (Fig. 29). (Figure 30 gives key to symbols in Fig. 29 and several other figures.) In the lower part of this section, laminae in siltstone and very fine arenite are gently curved, and sets of laminae are truncated at low angles by overlying sets; convex-upwards sets are also present (Fig. 31). These features, which are associated with wave and interference ripple marks, current scour casts in mudstone, and ball-and-pillow structures in thin arenite beds, are interpreted as hummocky cross-stratification. The thicker arenite beds of the formation are either plane-bedded or cross-bedded; those near the top of the section contain mudflakes, mudcracks and truncated wave ripple marks. Palaeocurrent data, based on primary current lineations, and the interpreted depositional environment for the Rooneys Formation are discussed with those for the Kurinelli Sandstone, as these two formations appear to be closely related genetically as well as spatially.

Kurinelli Sandstone

The Kurinelli Sandstone is made up predominantly of plane-bedded and cross-bedded arenite, generally in beds 0.3-3.0 m thick. In the lower part of its type section, in northwest HATCHES CREEK REGION (Fig. 28), the formation consists almost entirely of plane-bedded arenite which shows scours, load casts on a millimetre scale, and primary current lineations. Over a thickness of about 5 m in the middle of the type section a profusion of sedimentary structures are present, including current ripples, wrinkle marks, cross-bed sets 10-30 cm thick, small load casts, and mudcracks. Mudflake conglomerate and wave ripple marks are also found in the formation, but are rare in the type section.

In a measured section of the uppermost 36 m of the formation northwest of the Great Davenport mine in eastern KURUNDI REGION (locality A in Fig. 28), plane-bedded fine to medium-grained arenite alternates with cross-bedded arenite (Fig. 32). The cross-bed sets are up to 3 m thick and are mainly of trough type, although some wedge-shaped sets are also present (Fig. 33). There are also abundant soft-sediment deformation structures such as water-escape or load structures, and especially prolapsed cross-beds (Fig. 34). At four levels in this section, arenite fines upwards over less than 0.5 m into highly micaceous siltstone showing climbing ripples. Mudflake conglomerates are exposed both above and below the measured section.

In the upper part of the Kurinelli Sandstone in the northeast of the Murray Downs Dome, KURUNDI REGION, there are exposures of coarse-grained arenite with gritty interbeds. At one locality here (B in Fig. 28; at GR MS972815), a bed of poorly sorted pebbly arenite to conglomerate has subangular to subrounded clasts, up to 15 cm across, of quartz, grey and pink chert, quartzite and a fine-grained clay rock, set in a sandy to gritty matrix. About 200 m stratigraphically below the conglomerate bed, a bedding surface shows well-preserved casts of, and limonite pseudomorphs after, bladed gypsum crystals (Fig. 35).

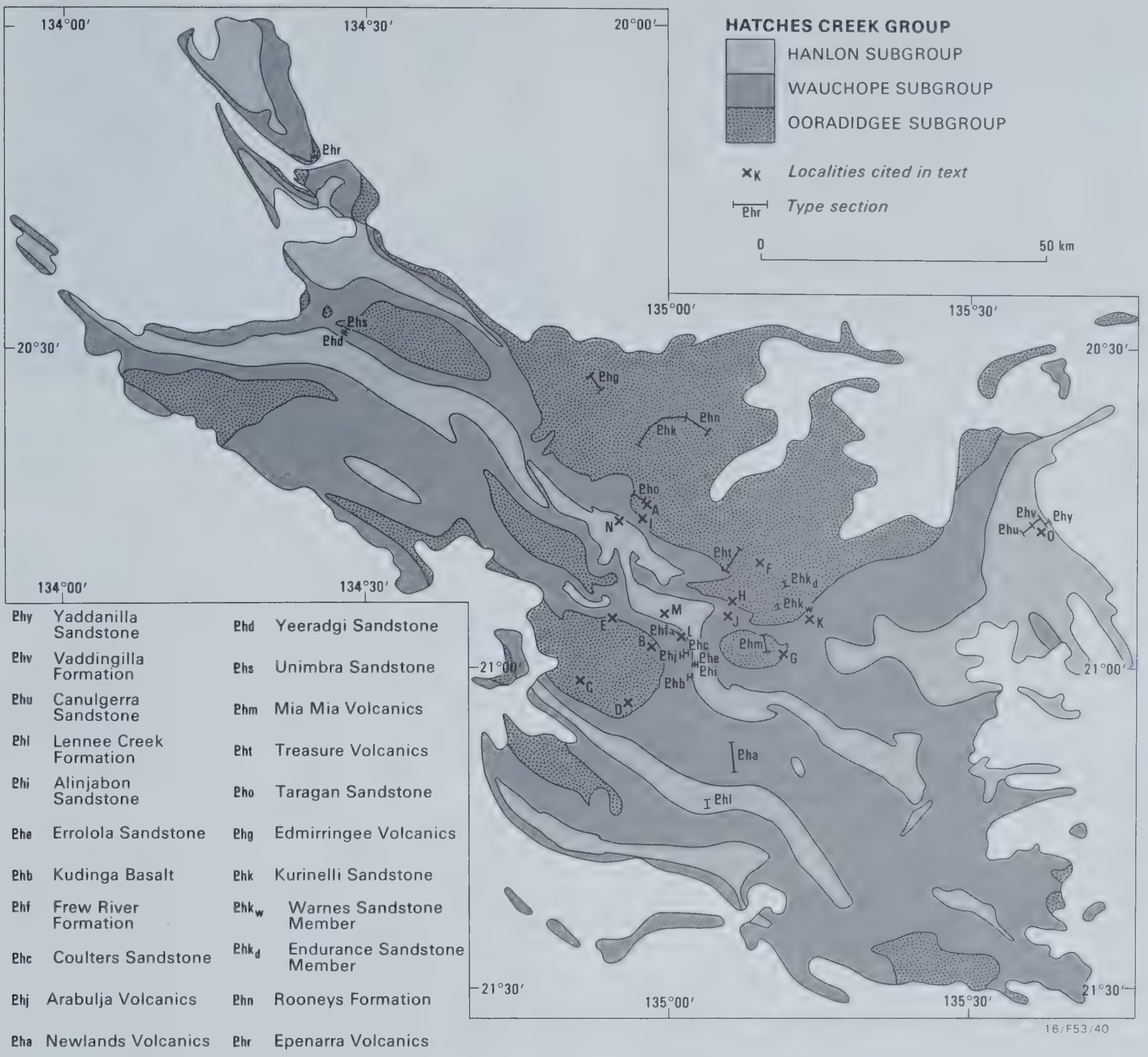


Fig. 28. Locations of Hatches Creek Group type sections and sedimentological study sites.

Lenses of fine-grained sedimentary rocks occur near both the base and top of the Kurinelli Sandstone. Some of those near the base represent tongues of Rooneys Formation, as in the type section, where very fine-grained, plane-bedded arenite at the base is overlain by several metres of laminated and rippled siltstone and shale interbedded on a centimetre scale. Some of the lenses have thin fining-up cycles, 1–5 cm thick; these begin with sharp-based coarse siltstone, which may be rippled, and grade up into finer siltstone and shale. Most of the ripple marks are wave ripples, although current ripples are also present. Some beds in the lenses show small-scale ball-and-pillow structures.

A fine-grained lens at the top of the Kurinelli Sandstone in the southwestern part of the Murray Downs Dome, ELKEDRA REGION (locality C in Fig. 28) consists of sharp-based ripple-laminated and plane-bedded very fine-grained arenite interbedded mainly on a 1–10 cm scale with fine siltstone and shale. This lens includes a 1 m-thick coarsening upwards sequence in which individual beds also thicken upwards, culminating in a 15 cm-thick bed of plane-bedded arenite; load casts are ubiquitous in the arenite beds (Fig. 36).

Measurements of cross-bed foresets and primary current lineations indicate sediment transport from west to east in the south (Fig. 37). A greater spread of transport directions is evident in the north, and near the Great Davenport mine there is a strong southwards-transport component (Fig. 37d, e).

Depositional environments. The Rooneys Formation and lower part of the Kurinelli Sandstone are interpreted as components of a deltaic complex, with the finer-grained micaceous beds representing delta-front deposits which were subjected to considerable wave action. Hummocky cross-stratification suggestive of the shoreface environment (Bourgeois, 1980; Moore & Hocking, 1983) provides evidence of strong wave and storm activity. The coarser beds are better sorted, and lack muscovite and clay matrix, suggesting higher energy deposition. Their occurrence at about a 200 m interval (Fig. 29) is of the same order as that suggested by Coleman & Wright (1975) for distributary mouth bars prograding over interdistributary sediments. Three arenite bands in the interval 350–400 m in the type section of the Rooneys Formation may represent repeated infilling of interdistributary areas. These bands contain truncated wave ripples, mudstone intraclasts and mudcracks—the earliest evidence in the Hatches Creek Group of very shallow-water deposition and subaerial exposure.

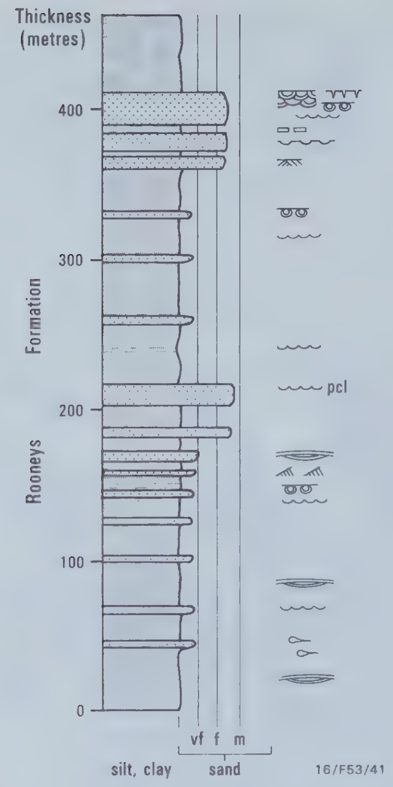


Fig. 29. Schematic representation of the central part of the type section for the Rooneys Formation, HATCHES CREEK REGION (centred at GR NT050186). For key to symbols see Fig. 30.

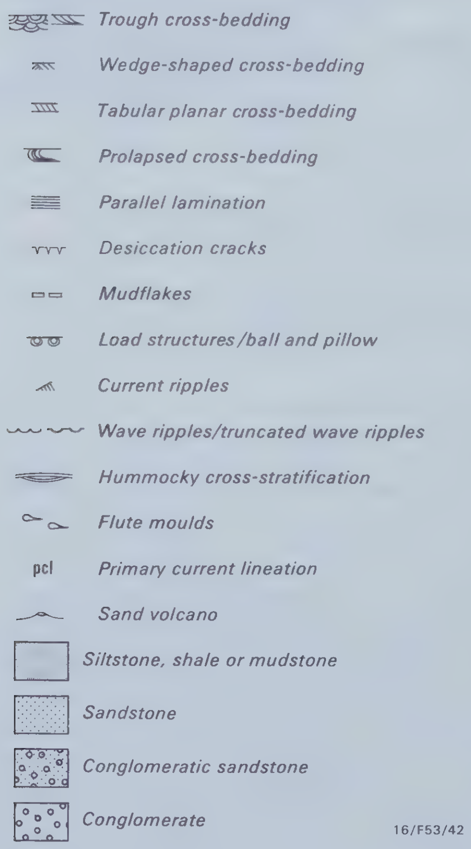

Trough cross-bedding
Wedge-shaped cross-bedding
Tabular planar cross-bedding
Prolapsed cross-bedding
Parallel lamination
Desiccation cracks
Mudflakes
Load structures/ball and pillow
Current ripples
Wave ripples/truncated wave ripples
Hummocky cross-stratification
Flute moulds
pcl
Primary current lineation
Sand volcano
Siltstone, shale or mudstone
Sandstone
Conglomeratic sandstone
Conglomerate
16/F53/42

Fig. 30. Key to symbols used in Figs 29, 32, 38, 39, 50, 53 and 56.

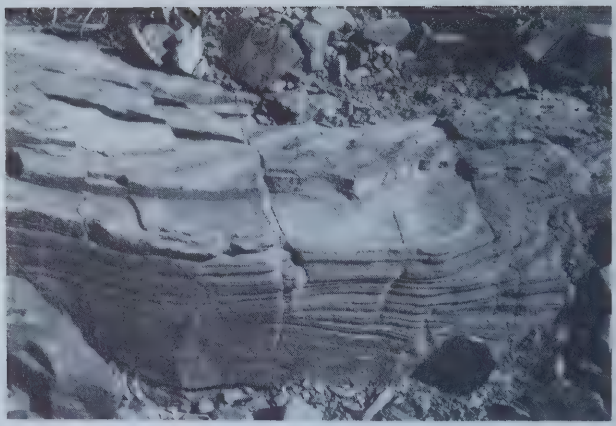


Fig. 31. Hummocky cross-stratification in beds of siltstone and fine-grained arenite at the base of the type section for the Rooneys Formation, HATCHES CREEK REGION (at GR NT152183). (M2697/41A)

The outstanding feature of the bulk of the Kurinelli Sandstone is the presence of plane-bedded and cross-bedded mudflaked arenite and the lack of either wave or current ripple marks. Most of the arenite probably represents continued progradation of a fluvial–deltaic complex. The limited palaeocurrent data indicate sediment transport from the west and northwest, suggesting that the complex prograded eastwards or southeastwards into either a marine or lacustrine environment.

The facies and bedforms present in the Kurinelli Sandstone allow some assessment of ‘fluvial style’ (Cotter, 1978) to be made in terms of braided versus meandering streams. Fining-up sequences, generally taken to be good indicators of meandering stream deposits, are present in the upper part of the formation (Fig. 32). However, the deposits appear to fit a braided stream model proposed by Walker & Cant (1979), in which trough and tabular cross-bedded sands are occasionally topped by finer sediments representing bar top or (rarely) flood plain deposits (see also Miall, 1978). Using depth-velocity diagrams (e.g., Harms & others, 1982), it can be inferred that fine-grained, plane-bedded arenite in the type section of the Kurinelli Sandstone was deposited in water 0.1 to 0.4 m deep, and in currents flowing at 0.6 to 0.8 m/sec. The cross-bedded arenite, generally of slightly coarser grain size, may have been deposited in slightly deeper water. Suggested water depths and velocities are consistent with deposition by shallow braided streams. Water up to several metres deep is indicated by the large bedforms (e.g., Fig. 33).

The fine-grained lens at the top of the Kurinelli Sandstone in the southwestern part of the Murray Downs Dome (locality C in Fig. 28) appears to represent floodplain deposits. The thin coarsening-upwards cycle in this lens may be a crevasse splay sediment, indicating that some meandering stream deposits may be present. Pseudomorphs after gypsum in the upper part of the Kurinelli Sandstone to the northeast suggest at least seasonally arid conditions, as does the presence of dolomite and salt-bearing claystone (Stewart & Blake, 1986). It seems likely that some salinas were developed on a flood plain within, or adjacent to, a major fluvial system flowing through an arid area.

Taragan Sandstone

The Taragan Sandstone in the Murray Downs Dome area (at localities B, D and E in Fig. 28) consists mainly of very thick bedded or massive conglomerate and conglomeratic arenite (Fig. 38). Both erosional and gradational bedding contacts are present. Medium to large-scale cross-bedding

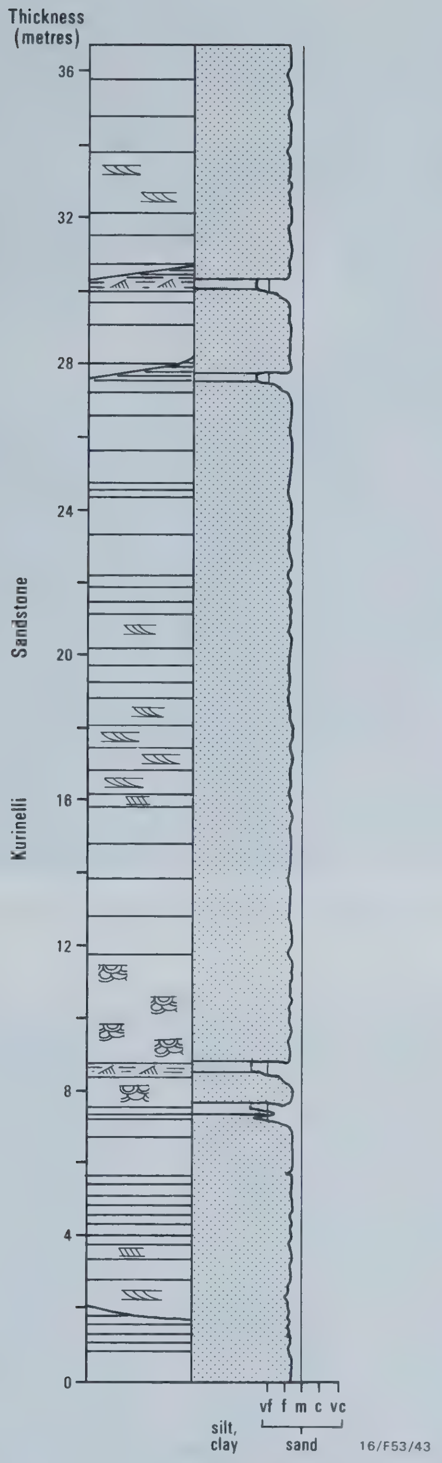


Fig. 32. Top 36 m of Kurinelli Sandstone underlying the Taragan Sandstone type section, KURUNDI REGION (at GR MT958062). For key to symbols see Fig. 30.

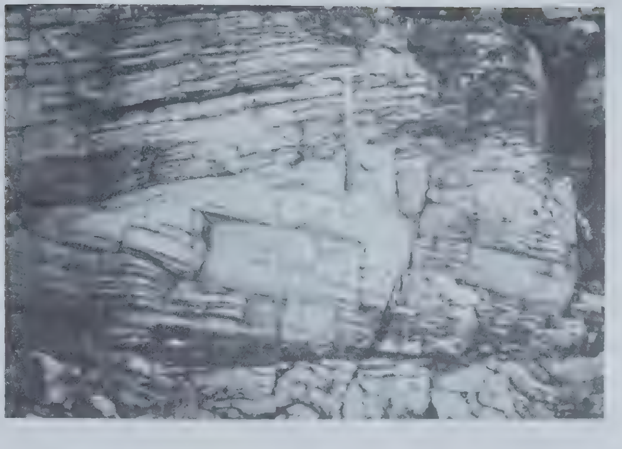


Fig. 33. Large-scale wedge-shaped cross-beds in Kurinelli Sandstone near the Great Davenport gold mine, KURUNDI REGION (locality A in Fig. 28; at GR NT975057). The distorted laminae at the bottom of the photo are probably a transverse view of a prolapsed cross-bed in which the current direction was away from the viewer. (M2697/2)

characterises the finer-grained parts of the sections. Trough cross-bedding predominates, but planar tabular varieties are also present; ripple marks are very rare.

In the type section in eastern KURUNDI REGION (Fig. 28), three unnamed members have been recognised (Fig. 39). Arenites making up the lower member are plane-bedded to strongly trough and planar-tabular cross-bedded; mudflakes occur in the foresets, and oversteepened and overturned (prolapsed) foresets are common in thick-bedded arenites. Fining-upwards cycles are present in the lower part of this member, and some lateral accretion bedding has been recognised (Fig. 40), but ripple marks are absent, except at the transition into the middle member, where wave ripples are preserved. The upper member (and most of the formation in other areas) is dominated by plane-bedded pebble conglomerate and pebbly arenite. The uppermost bedding surface of this member in the type section contains well-preserved sand volcanoes (Figs 41–43).

The measurement of foresets to cross-beds (Fig. 44) in the vicinity of the type section indicates that the lower member was derived from the west and southwest, and the upper member from the north. The middle member yields a bimodal pattern, and in conjunction with the presence of wave ripples, suggests a tidally influenced marine environment. The Taragan Sandstone in the Murray Downs Dome area was largely transported from the west.

Depositional environments. The coarse, pebbly character of the Taragan Sandstone and its generally conformable relation to the underlying Kurinelli Sandstone suggest that it too is predominantly fluvial. The formation shows major lateral and vertical changes, and the following three major facies can be recognised.

Alluvial fan facies. This is best-developed in the Murray Downs Dome area, where it constitutes the whole formation. It is characterised by massive plane-bedded and cross-bedded conglomerate and trough cross-bedded arenite which can be equated with lithofacies *Gm, Gp, Gt*, and *St* of Miall (1978) and Rust (1978). The formation here is tentatively judged to represent alluvial fan deposits on the basis of rapid lateral variation in grain size and mean current directions indicating transport from the southwest in the south and from the west-northwest 15 km to the north (Fig. 38b): the different current directions are thought to reflect dispersion from different alluvial fans. In the south, the initial coarsening-upwards sequence (Fig. 38a) and the repeated upwards-fining sequences above may be due to initial tectonic uplift followed by repeated abandonment of fan segments in the manner described by Heward (1978). The overall fining-upwards trend apparent from measures of maximum clast size in two sections (Figs 38a and b) may be the consequence of cessation or waning of tectonic activity, resulting in a gradual lessening of relief, a drop in stream power, and a decrease in grain-size of material transported. The alluvial fan facies also includes the upper member of the Taragan Sandstone in the type section (Fig. 39) and in outcrops to the east, in HATCHES CREEK REGION. The rocks here are generally

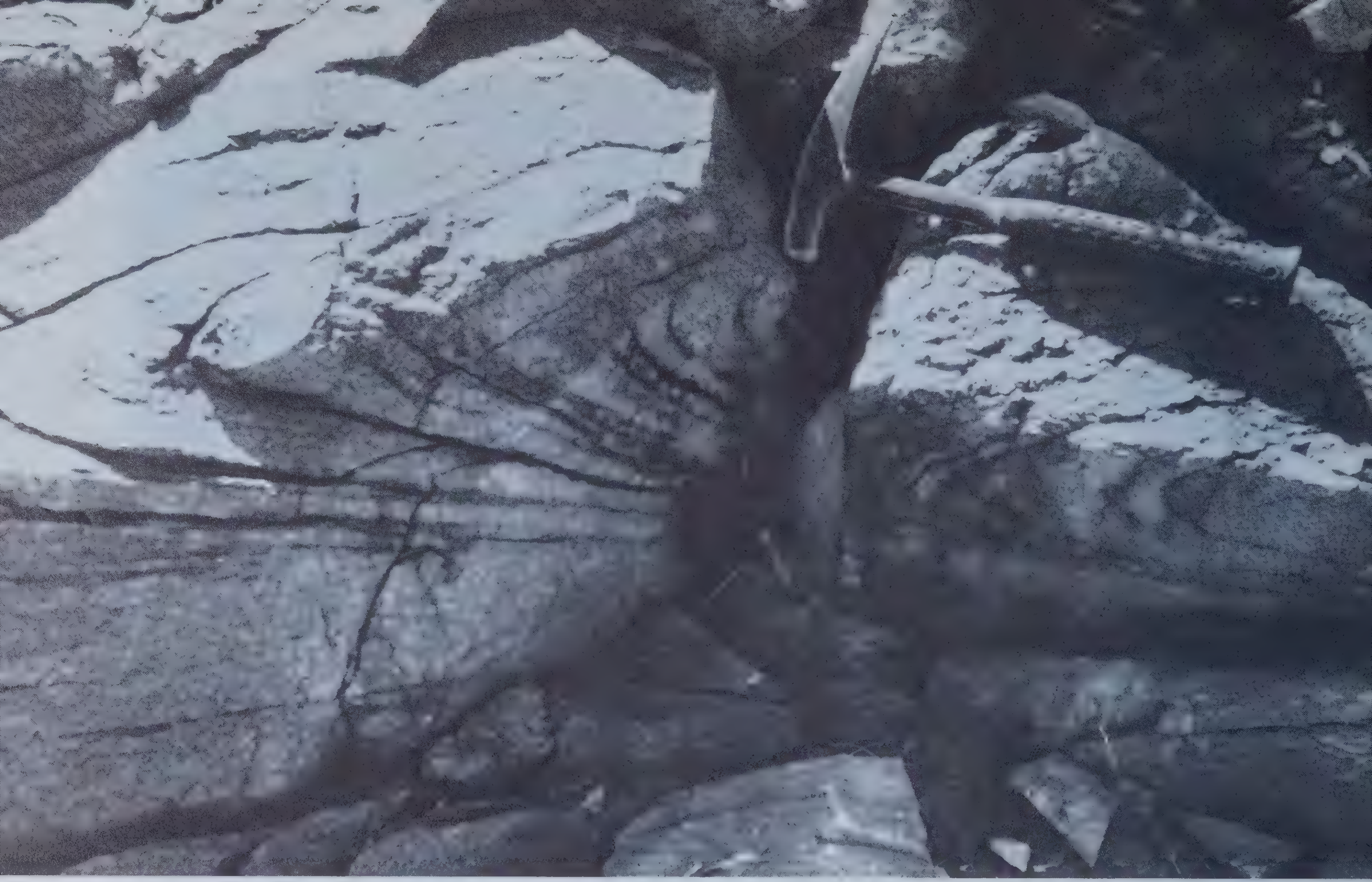


Fig. 34. Prolapsed (also termed recumbent folded) cross-bedding in Kurinelli Sandstone in southwest ELKEDRA REGION (at GR NS492270). Such deformed cross-beds are common in the lower and middle Hatches Creek Group. (M2696/8)

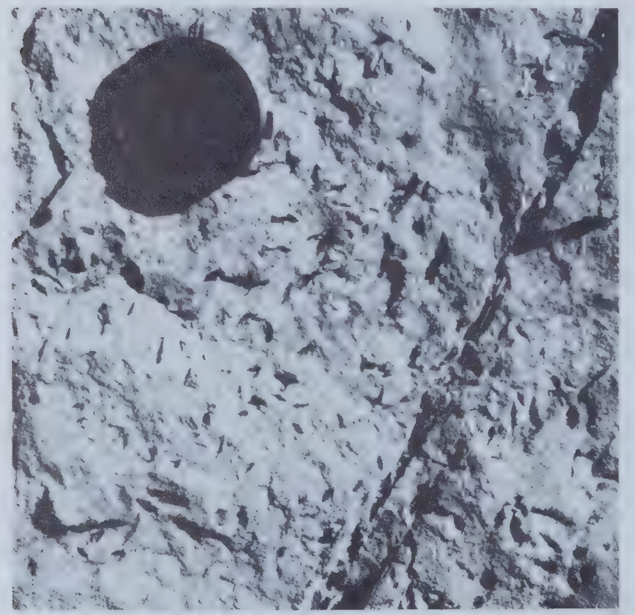


Fig. 35. Limonite pseudomorphs after gypsum in the upper part of the Kurinelli Sandstone on the northeast side of the Murray Downs Dome, KURUNDI REGION (locality B in Fig. 28; at GR MS968811). Lens cap is 50 mm across. (M2696/11)

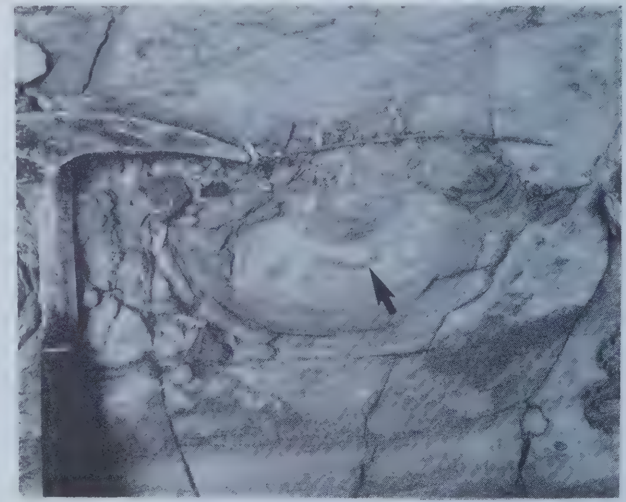


Fig. 36. Load casts in the upper fine-grained lens of Kurinelli Sandstone on the west side of the Murray Downs Dome, ELKEDRA REGION (locality C in Fig. 28; at GR MS846751). Arrowed structures are earlier load casts incorporated into the larger, later ones. (M2696/9)

finer-grained than those in the Murray Downs Dome, most being pebbly arenites, although there are a few cobble-rich intervals. They appear to be laterally extensive, and may represent either distal alluvial fan or pebbly braided stream deposits; the few palaeocurrent readings measured indicate derivation from an upland to the north (Fig. 44).

Meandering stream facies. The fining-upwards sequences in the lower part of the basal member in the type section (Fig. 39) have a much higher proportion of siltstone and mudstone than the uppermost part of the underlying Kurinelli Sandstone, and are interpreted as a meandering stream facies.

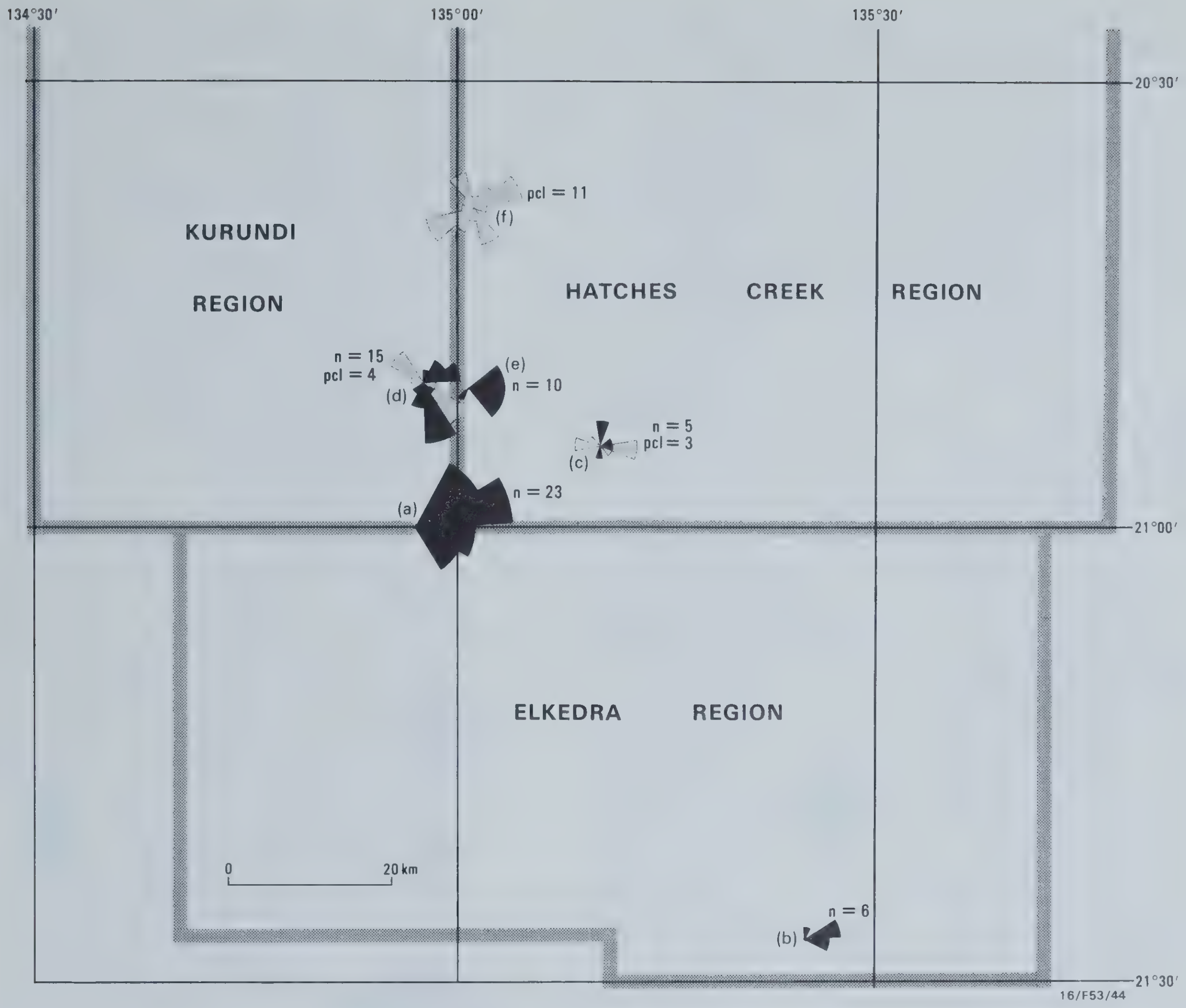


Fig. 37. Palaeocurrent data for Kurinelli Sandstone, based on cross-bed foresets except where stated: (a) Murray Downs Dome, KURUNDI REGION and ELKEDRA REGION; (b) southeastern ELKEDRA REGION; (c) northeast part of Hatches Creek tungsten field, HATCHES CREEK REGION (includes some current lineations); (d) underlying the Taragan Sandstone type section, KURUNDI REGION; (e) Great Davenport gold mine area, KURUNDI REGION (includes current lineations); (f) primary current lineations in type-section area in HATCHES CREEK REGION. 30° class interval used throughout.

Above the 85 m level, siltstone is absent and the member is represented by arenite which is distinctly trough cross-bedded, mudflake-rich, and vaguely cyclic on a 10 m scale; however, abundant mudflakes indicate the presence of some fine-grained over-bank or bar sediments, and the cyclicity is interpreted as the stacking of channel sands (i.e., multistorey sands) in a meandering stream environment.

Marine facies. The occurrence of wave rippled arenite and finer-grained sediments in the middle member of the Taragan Sandstone in the type section indicates deposition in a standing body of water. Although a lacustrine environment may seem more likely in an otherwise fluvial-dominated regime, the bimodality of palaeocurrents (Fig. 44) is best explained by tidal influence, and it is therefore suggested that this member represents a minor marine transgression. The environment may have been a large bay or estuary swept by tidal currents. A white, strongly cross-bedded, well-sorted arenite at the top of the middle member may be a nearshore facies.

Treasure Volcanics

Ten mappable sedimentary members consisting mainly of arenite are present in the type section of the Treasure Volcanics, in western HATCHES CREEK REGION (Fig. 28). Several of these members lens out within a few kilometres. Fewer sedimentary interbeds are present in most other sections. In the following account the ten members in the type section are referred to as S1 (oldest) to S10 (youngest).

The arenites in the Treasure Volcanics are medium to thick-bedded. Some show poorly preserved cross-beddding, but in many outcrops no sedimentary structures are visible, presumably having been destroyed shortly after deposition. However, well-preserved structures at two localities indicate depositional environments. At GR NS160952, HATCHES CREEK REGION (locality F, Fig. 28), current ripples, megaripples (dunes), and primary current lineation are preserved on the upper surface of an 8-m thick massive, cross-bedded, medium-grained to pebbly arenite bed within a sedimentary member that can be traced to S2 in the type section, 4 km to the west-northwest. This arenite is overlain by an 18 m-thick structureless to faintly laminated claystone with sparse thin laminae of siltstone and very fine arenite. The exposed bedding plane covers an area of several hundred square metres (Fig. 45), and lies in the nose of a gently plunging syncline. Spectacular megaripples exhumed from beneath the claystone capping (Fig. 46) have straight to

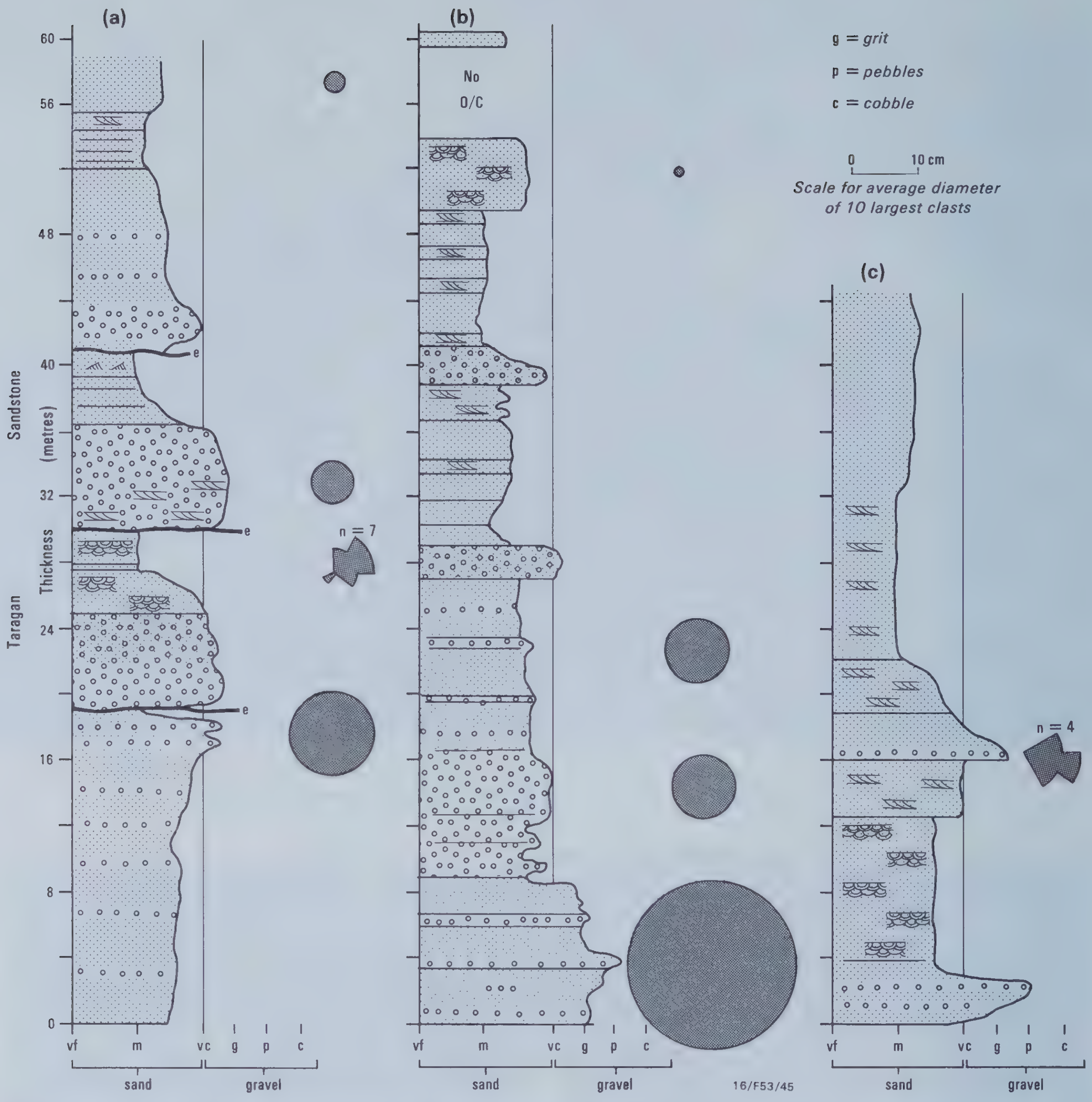


Fig. 38. Measured sections of Taragan Sandstone in the Murray Downs Dome: (a) 27 km east of Murray Downs homestead, ELKEDRA REGION (locality D in Fig. 28; at GR MS933716) — heavy lines mark erosion surfaces; (b) northeast flank of dome, KURUNDI REGION (near locality B in Fig. 28; at GR 972814); (c) northern flank of dome, KURUNDI REGION (locality E in Fig. 28; at GR MS902865). Black circles indicate average size of the 10 largest clasts. For key to symbols see Fig. 30.

sinuous crests, heights of 0.1 to 0.3 m, and wavelengths of 2 to 3 m. In some cases, individual foreset laminae are visible on the crestal portions of the megaripples, and a brinkline is well preserved (Fig. 47). A small field of ripples at the same level nearby has formed between a low slip face of a megaripple and a plane bed showing primary currents lineation (Fig. 48).

Other sedimentary structures are present in members S7 to S10 in the type section in HATCHES CREEK REGION, around GR MT109050. The arenite in S7 is medium-grained, well-sorted, in beds 0.5-1 m thick, cross-bedded and mudflake-rich. Two palaeocurrent readings indicate current directions nearly 180 degrees apart (towards 070° and 255°). Arenite in S8 is thinner bedded (5-20 cm), strongly wave-rippled, and contains mudflakes and mudcracks. At one exposure the wave ripples have flattened crests and sharp troughs, indicating emergent conditions (Reineck & Singh, 1980, p. 442). This arenite grades up, over about 0.5 m, into purple and green fine siltstone and shale. S9 consists of massive, silicified and brecciated arenite with no structures preserved, except for a few small patches of wave ripples on the top surface. A 2 m-deep channel is discernible in S10 at GR MT110938. The channel arenite is vaguely cross-bedded and is overlain by plane-bedded quartz arenite in beds 0.5-1 m thick.

Depositional environments. The strongly cross-bedded, poorly sorted pebbly arenite in S2 at locality F in Fig. 28 is considered to be a fluvial channel sand deposit. The absence of erosional features on the megaripples and the occurrence of a thick claystone above them indicate an abrupt fall in current velocity (e.g., Allen, 1982, p. 495). This may have been caused by neck cutoff of a meander loop in a meandering stream system, resulting in channel sand being overlain by a clay-plug deposited in an oxbow lake: a similarly well-

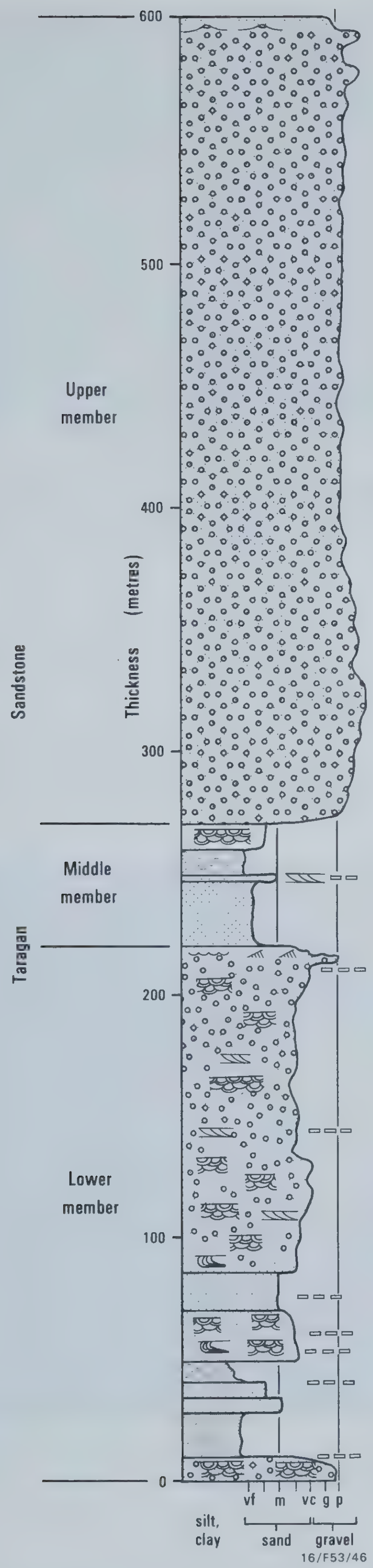


Fig. 39. Type section of the Taragan Sandstone, KURUNDI REGION (centred at GR MT950069). The lower and middle members were measured by Jacob Staff; the thickness of the poorly exposed upper member was calculated using measured dips and photo-interpreted boundaries. For key to symbols see Fig. 30.

preserved field of megaripples and other structures from the Carboniferous of eastern Canada has been interpreted in this way by McCabe (1978); alternatively, the stream may have been diverted by volcanic processes.

The structures preserved in arenites of members S7 to S10 in the type section, particularly the truncated wave ripples, are more suggestive of a shoreline environment than fluvial conditions. The mineralogical maturity of the sands in member S10 may also reflect a shoreline environment (marine or lacustrine), with unstable grains being removed during continual abrasion. If these interpretations are correct, a transition from a fluvial to a shallow aqueous environment is recorded in members S3 to S7 of the Treasure Volcanics.

Unimbra Sandstone

Most of the Unimbra Sandstone is medium to very thick-bedded, and in many places is cross-bedded; ripple marks appear to be uncommon. Cross-beds are generally of the trough type, with curved bounding surfaces, and range from 0.2 to 2 or more metres thick; deformed and prolapsed foreset laminae are present in several places.

Although no members have been formally mapped within the Unimbra Sandstone, lithologic variations on a mappable scale are present. For example, in the type section in DEVILS MARBLES REGION (Fig. 28), two pale coloured, ridge-forming conglomeratic bands are separated by a darker recessive band of medium-grained, brown to pink, flaggy to blocky arenite. In the eastern part of the Mia Mia Dome in HATCHES CREEK REGION (locality G in Fig. 28), a 600 m-thick lower member, consisting of massive, structureless and plane-bedded to gently inclined-bedded, medium-grained quartz arenite and sublithic arenite, is overlain by a 1000 m-thick upper member of flaggy to massive, trough cross-bedded, medium-grained to pebbly sublithic arenite. The upper member is similar to the entire Unimbra Sandstone at Unimbra Rockhole to the northwest (HATCHES CREEK REGION, GR NT108888), where the formation is less than 200 m thick.

Structureless beds, or very thick beds with low-angle inclined laminae, characteristic of beach deposits (Reineck & Singh, 1980, p. 364), were observed in the central part of the formation near the Julia Basin Rockhole in eastern KURUNDI REGION (locality J, Fig. 28; GR MT960030), and in the basal member in the eastern part of the Mia Mia Dome, HATCHES CREEK REGION (locality G, Fig. 28).

In southeastern ELKEDRA REGION, most of the formation consists of medium-grained feldspathic or lithic arenite in which oversteepened and overturned foreset laminae, and mudflake-littered bedding planes, are common.

Depositional environments. The Unimbra Sandstone exemplifies the common problem of distinguishing marine from non-marine (i.e., fluvial or lacustrine) facies in Precambrian rocks (e.g., Pettijohn & others, 1973; Long, 1978, p. 313; Dott, 1983). The formation as a whole appears to be a series of sandstone sheets, and the criterion of sand-body shape is not particularly useful. Interpretations of environments are therefore based mainly on texture, sorting and sedimentary structures. The pebbly and cross-bedded arenites common in the type section, in the Unimbra Rockhole area, and in the upper part of the Mia Mia Dome section, are regarded as fluvial, whereas the more massive medium arenites at Julia Basin Rockhole and in the lower part of the Mia Mia Dome section are thought to be shallow-marine beach deposits.

The distribution of probable marine and non-marine facies suggest that over most of its outcrop the Unimbra Sandstone records a marine transgression from the east, followed by a regression. As the formation intertongues in places with the underlying Treasure Volcanics, the transgressive marine facies

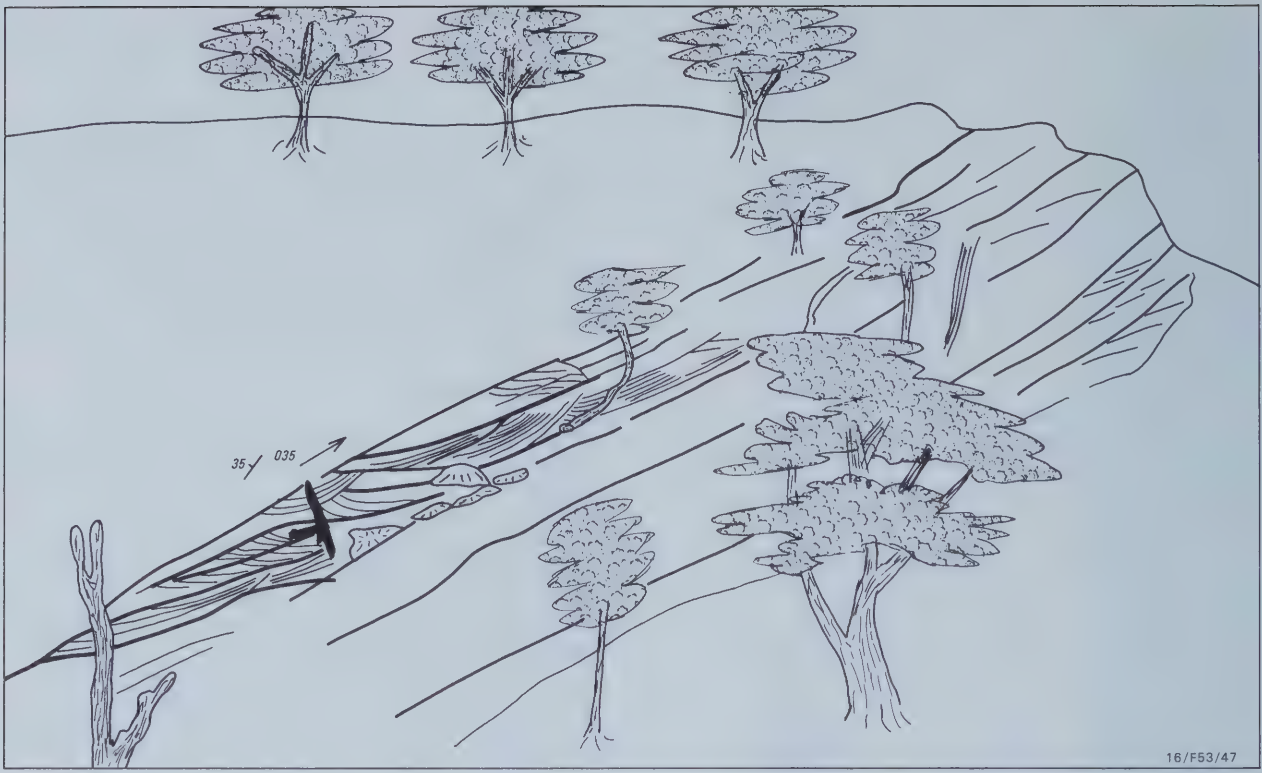


Fig. 40. Lateral accretion bedding 10 m above base of the Taragan Sandstone in its type section, KURUNDI REGION (at GR MT956064). Regional bedding dips at 35° to the left (towards 305°), whereas the main lateral accretion surfaces (heavy lines) are less steep (dip at only about 25°) and indicate accretion almost updip, towards 085°. Thin lines are foreset laminae.

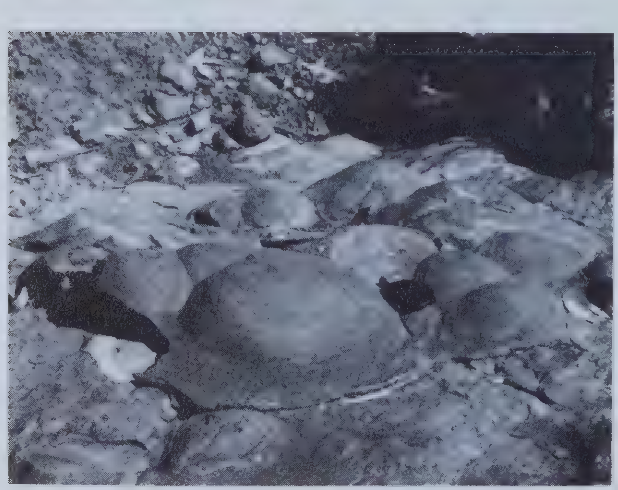


Fig. 41. Sand volcanoes on the bedding plane of the uppermost arenite bed in the Taragan Sandstone type section, KURUNDI REGION (at GR MT944073). Largest structure is about 15 cm across. (M2697/10)

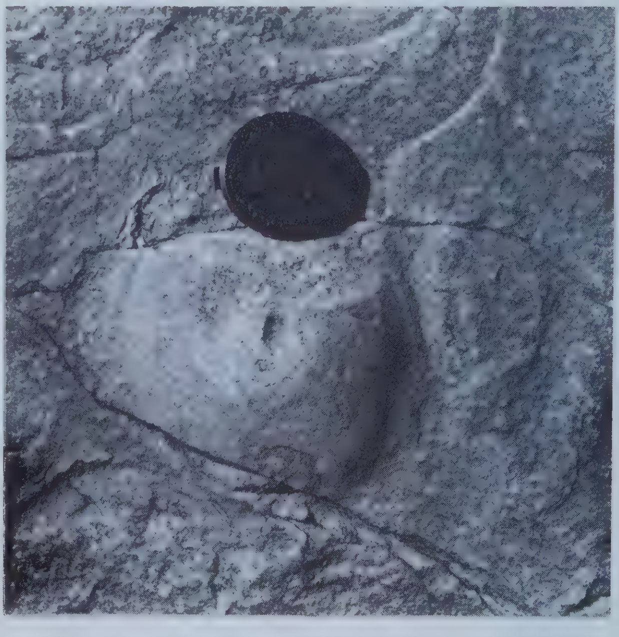


Fig. 42. Plan view of sand volcano showing almost symmetrical form and small summit depression. Same locality as Fig. 41. (M2697/11)

of the lower part may be equivalent to the marine facies in the upper part of the Treasure Volcanics. However, conglomeratic beds at the base of the Unimbra Sandstone in KURUNDI REGION are probably fluvial; they are essentially a continuation of fluvial Taragan Sandstone deposition, and may be equivalent to some or all of the fluvial members, such as S2, in the Treasure Volcanics to the east. The fluvial facies forming the upper part of the Unimbra Sandstone in the Mia Mia Dome section is the only facies present in parts of the Davenport province.

Palaeocurrents. Only 26 current measurements, all on foreset bedding, were obtained for the Unimbra Sandstone (Fig. 49), an inadequate number for detailed analysis. Readings from the fluvial facies around Unimbra Rockhole indicate generally east-flowing streams (Fig. 49a); those from the Mia Mia Dome (Fig. 49b) result from currents flowing to the southeast; those from the shallow marine facies at Julia Basin Rockhole (Fig. 49c) show considerable dispersion, and do not give reliable information on either source regions or palaeoslopes.

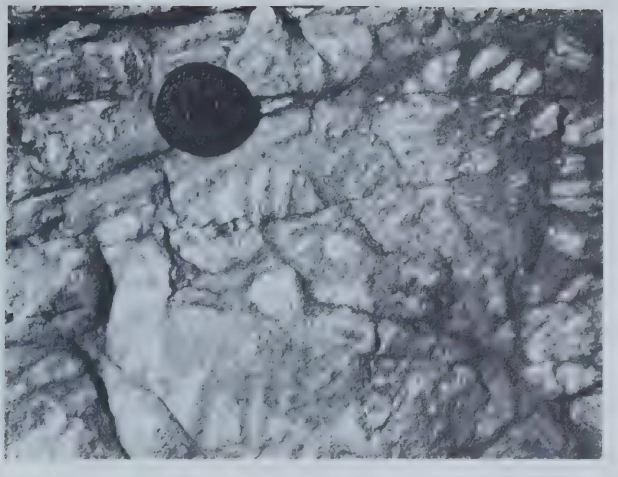


Fig. 43. Sand volcanoes with a petal-like structure due to selective silification, possibly of individual lobes of sand which avalanched down the flanks of the structure during growth. Same locality as Fig. 41. (M2697/1)

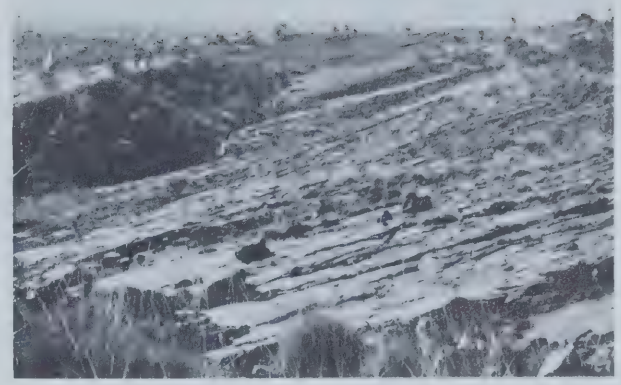


Fig. 45. Gently dipping bedding plane of arenite within the Treasure Volcanics in HATCHES CREEK REGION (locality F in Fig. 28; at GR NS161950). Bedforms shown in Figs 46–48 are at base of small scarp (arrowed). (M2697/3)

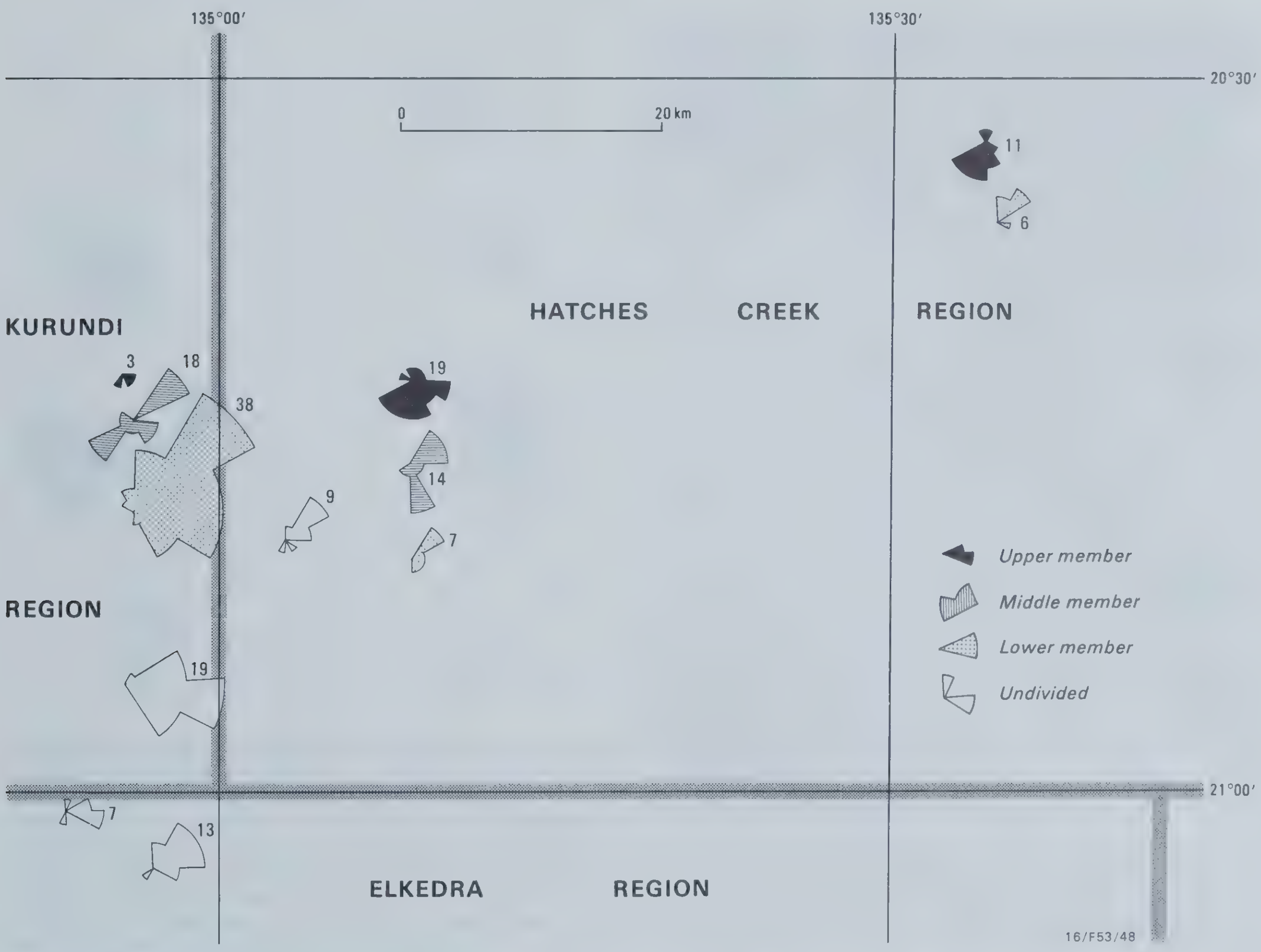


Fig. 44. Taragan Sandstone palaeocurrents. All readings are of cross-bed foresets; 30° class interval. Where readings for separate members are given, the geographic locality is in the position shown by the rose diagram for the lower member.

Yeeradgi Sandstone

The Yeeradgi Sandstone consists predominantly of reddish brown, cross-bedded, fine-grained sublithic and subarkosic arenite. In several areas, it also includes laminated siltstone and shale units up to several tens of metres thick. The arenites are characteristically trough cross-bedded in sets, with 0.5–2 m thick gently curved foresets up to several metres in length. The bounding surfaces of cosets are subparallel (Nu- or Pi-type of Allen, 1963), probably because exposed cross-sections of the beds are roughly parallel to the sediment transport direction. Palaeocurrent data from the type section in DEVILS MARBLES REGION indicate transport to the southeast (Fig. 49d). Many beds appear to fine upwards; e.g.,

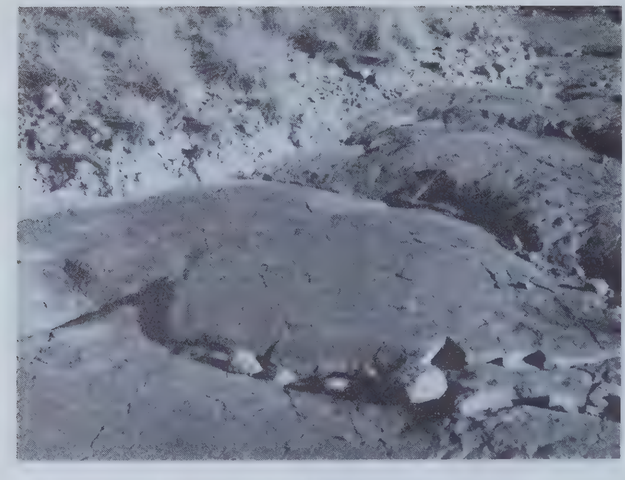


Fig. 46. Train of megaripples of 2 to 3 m wavelength; slip faces are arrowed. Note the irregular surface on the almost closed trough of the closest megaripple, and the abrupt change in slope just below the ripple crest. Same locality as Fig. 45. (M2561/10A)

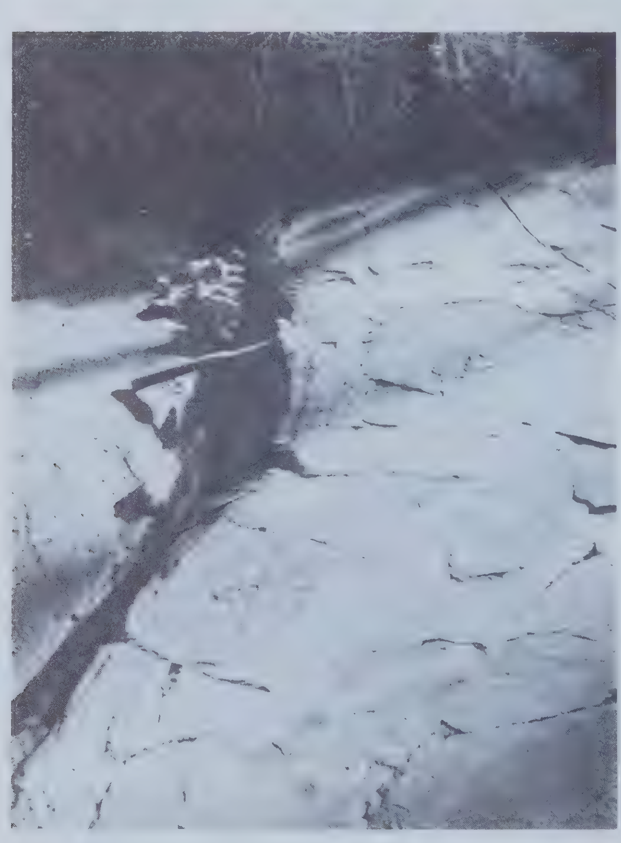


Fig. 47. Detail of megaripple showing faint foreset laminae preserved on the stoss surface, sharp brinkline, and well-preserved slip face. Primary current lineations can be seen on the next megaripple downstream. Same locality as Fig. 45. (M2696/7)

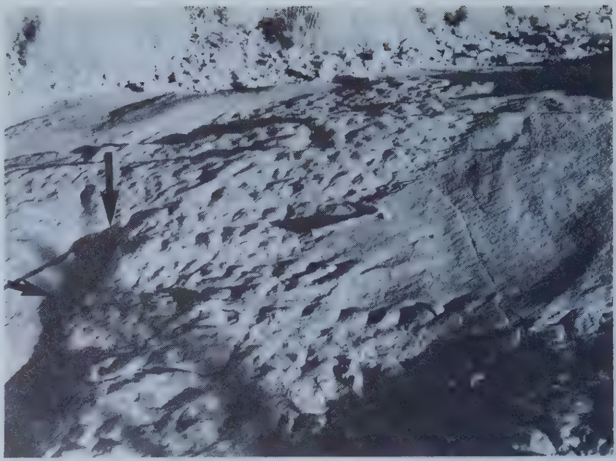


Fig. 48. Megaripple (arrowed, on left) transitional into lunate and linguoid ripples (centre), and a plane bed with primary current lineation (right). These features suggest an abrupt slowing and shawllowing of the fluvial current that producted the megaripples. Same locality as Fig. 45. (M2696/4)

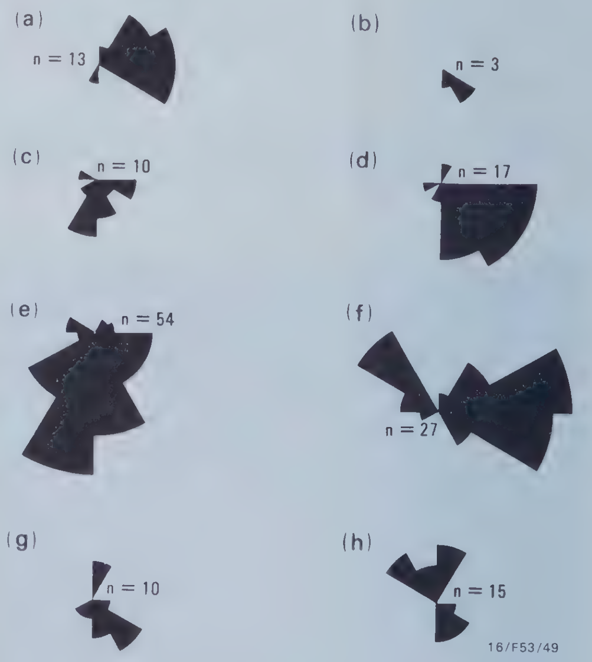


Fig. 49. Palaeocurrent data for Unimbra Sandstone and younger sandstone units of the Hatches Creek Group: (a) Unimbra Sandstone near Unimbra Rockhole, HATCHES CREEK REGION; (b) Unimbra Sandstone on east side of the Mia Mia Dome, HATCHES CREEK REGION; (c) Unimbra Sandstone northwest of Julia Basin Rockhole, KURUNDI REGION; (d) Yeeradgi Sandstone, mostly in eastern DEVILS MARBLES REGION; (e) Coulters Sandstone — about half of the readings are from the type section, remainder from throughout the Davenport province; (f) Errolola Sandstone near Julia Basin Rockhole, KURUNDI REGION; (g) Errolola Sandstone in southeast KURUNDI REGION; (h) Canulgerra Sandstone in eastern HATCHES CREEK REGION.

in DEVILS MARBLES REGION, at GR MT445355, one bed consists, from bottom to top, of plane-bedded fine arenite 0.1 m thick, 0.2 m of climbing ripple-laminated, fine arenite, and capped by 0.1 m of quartz-rich coarse siltstone. Graded siltstone and shale several metres thick in HATCHES CREEK REGION (at locality M, Fig. 28; GR NS103860) comprise sharp-based units 5–50 mm thick of dark greyish green, biotite-rich coarse siltstone grading up into very light green fine micaceous siltstone and shale. Finely laminated ripple-bedding only one ripple thick (5–10 mm) is apparent in some of the coarse siltstone beds; the ripples generally have sharp tops.

Depositional environments. The arenites are interpreted as mainly fluvial deposits representing a continuation of non-marine deposition from the Unimbra Sandstone. The abrupt change from Unimbra to Yeeradgi-type arenites may be due partly to a large input of volcanic detritus and partly to a shift in facies belts related to reduced relief in the source area. The fining-up bed described from DEVILS MARBLES REGION probably resulted from processes on a small fluvial bar. The graded siltstone/ripple-laminated siltstone and shale beds in HATCHES CREEK REGION are similar to recessive beds at the base and top of the Kurinelli Sandstone, and are interpreted as levee and/or overbank deposits.

Coulters Sandstone

In its type section in southwest HATCHES CREEK REGION (centred at GR 031801), the Coulters Sandstone (Fig. 50) consists of a lower member, 130 m thick, comprising massive and trough cross-bedded, medium-grained, slightly feldspathic arenite, with rare grit and pebble bands near the base; a middle member, 180 m thick, of mainly fine-grained arenite showing low angle cross-beds (Fig. 51), but also including a recessive unit of very fine-grained, highly lithic/feldspathic, well-sorted arenite; and an upper member, 194 m thick, of less well-sorted, generally medium to coarse-grained, trough cross-bedded arenite with some plane-bedded scattered grit and pebble layers. The arenite in the uppermost 10 m becomes flaggy, finer-grained, and ripple marked.

Three members are also present to the east, east of the Mia Mia Dome. At locality K in Fig. 28, a resistant basal member thickens southwards from 110 m (at GR NS246866, HATCHES CREEK REGION) to 500 m over a distance of 7 km. It is overlain by a finer-grained recessive member which may be the same as that in about the middle of the type section. Cross-beds are well preserved in the basal member at GR NS246866 (Fig. 52), where the larger sets are tabular planar in style, and range from 0.1 to 0.5 m in thickness; reactivation surfaces present are overlain by smaller trough cross-beds in which the sets are 0.1–0.2 m thick. Most of the reactivation surfaces die out downslope, and may have been produced by the migration of ripples over the crests of large bedforms (megaripples or sandwaves)—a constant-stage mechanism (McCabe & Jones, 1977). The overlying small trough cross-beds could indicate migration of megaripples obliquely across large bedforms. About 3.4 km to the south-southwest, the basal member has thickened to 240 m. At this locality, trough cross-beds are poorly preserved, although the top of one massive, medium to very coarse arenite bed is strongly current-rippled, with the ripple troughs being filled with shale. The basal member doubles its thickness to 500 m at 3.5 km to the south, where cross-bed sets up to 2 m thick are present. In the upper member trough cross-beds are common throughout, except at the top, where current ripple marks predominate; large symmetrical (wave) ripples are present at the base of the overlying Frew River Formation (Fig. 54).

Depositional environment. The Coulters Sandstone is probably a shallow-marine unit, as it was deposited over an area of about 15 000 km^2 in the Davenport province, and extended over a much larger area assuming its correlation with similar arenites in the Tomkinson Creek beds is correct (Blake, 1984). The low-angle cross-bedding in the middle member of the type section may be of the beach type. The bedforms in the basal member east of the Mia Mia Dome could have formed as tidal shelf sandwaves. The almost unimodal palaeocurrent measurements, indicating transport to the south (Fig. 49), could be seen as evidence for fluvial environments but the nature of the transition into the overlying Frew River Formation (see below) supports the shallow-marine interpretation.

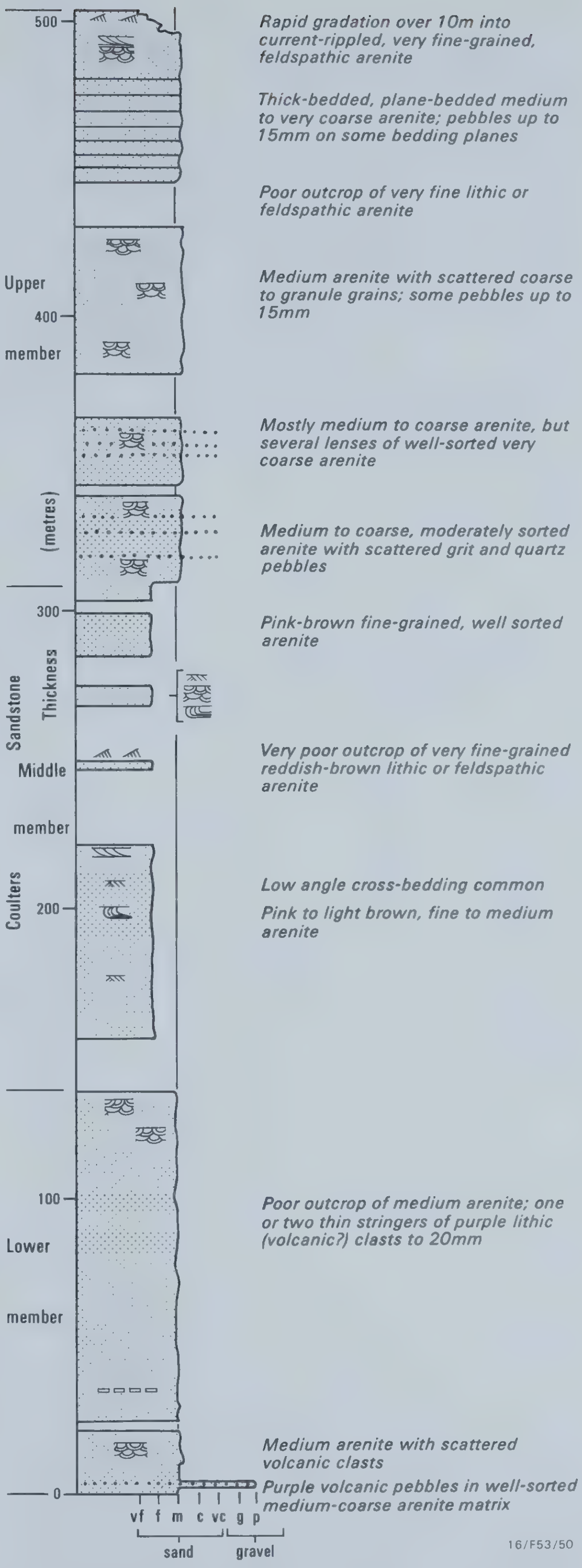

500
400
300
200
100
0
Upper
member
Coulters Sandstone
Thickness (metres)
Middle
member
Lower
member
Rapid gradation over 10m into current-rippled, very fine-grained, feldspathic arenite
Thick-bedded, plane-bedded medium to very coarse arenite; pebbles up to 15mm on some bedding planes
Poor outcrop of very fine lithic or feldspathic arenite
Medium arenite with scattered coarse to granule grains; some pebbles up to 15mm
Mostly medium to coarse arenite, but several lenses of well-sorted very coarse arenite
Medium to coarse, moderately sorted arenite with scattered grit and quartz pebbles
Pink-brown fine-grained, well sorted arenite
Very poor outcrop of very fine-grained reddish-brown lithic or feldspathic arenite
Low angle cross-bedding common
Pink to light brown, fine to medium arenite
Poor outcrop of medium arenite; one or two thin stringers of purple lithic (volcanic?) clasts to 20mm
Medium arenite with scattered volcanic clasts
Purple volcanic pebbles in well-sorted medium-coarse arenite matrix
vf f m c vc g p
sand
gravel
16/F53/50

Fig. 50. Type section of Coulters Sandstone, southwestern HATCHES CREEK REGION. For key to symbols see Fig. 30.

Frew River Formation

The Frew River Formation is the only carbonate-rich formation in an otherwise siliciclastic/volcanic succession. Pyritic and carbonaceous shales may dominate this unit, but they crop out very poorly, and most exposures are of dolomitic rocks.

In southwest HATCHES CREEK REGION, the transition from Coulters Sandstone to Frew River Formation (Fig. 50,

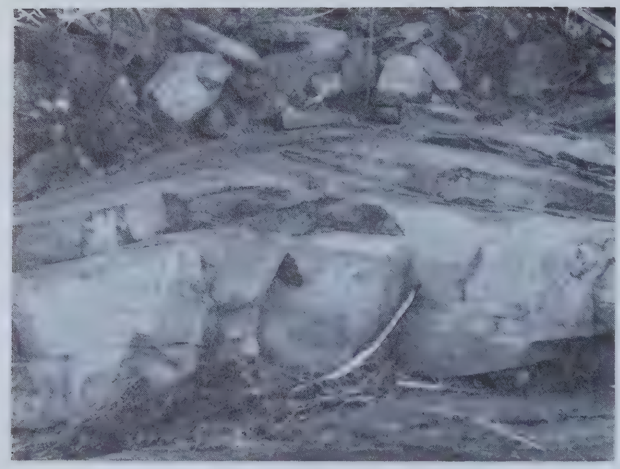


Fig. 51. Low-angle cross-bedding at 216 m in type section of Coulters Sandstone, HATCHES CREEK REGION. Although this structure is similar to that expected in giant wave ripples, it is more likely to be the intersection zone of two large, very shallow trough cross-beds. Scale bar is 0.2 m long. (M2561/2A)

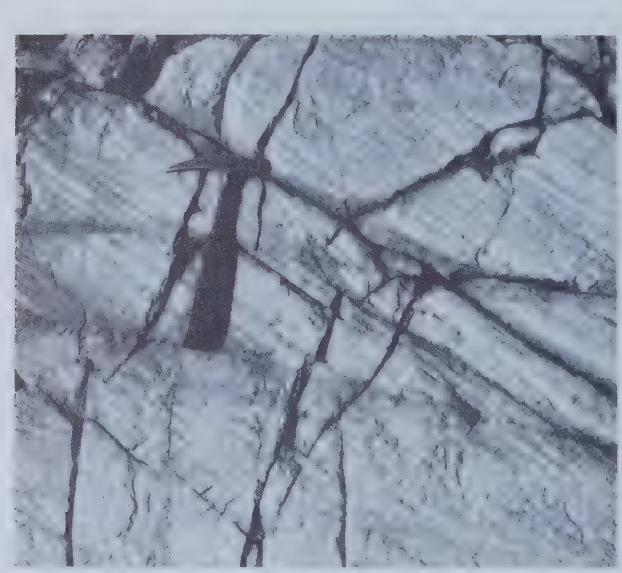


Fig. 52. Large-scale planar cross-beds with associated trough cross-beds in Coulters Sandstone, HATCHES CREEK REGION (at locality K, Fig. 28; GR NS246866). Regional bedding is marked by the bedding planes behind the middle of the hammer and above, whereas those below the hammer are reactivation surfaces. (M2697/4)

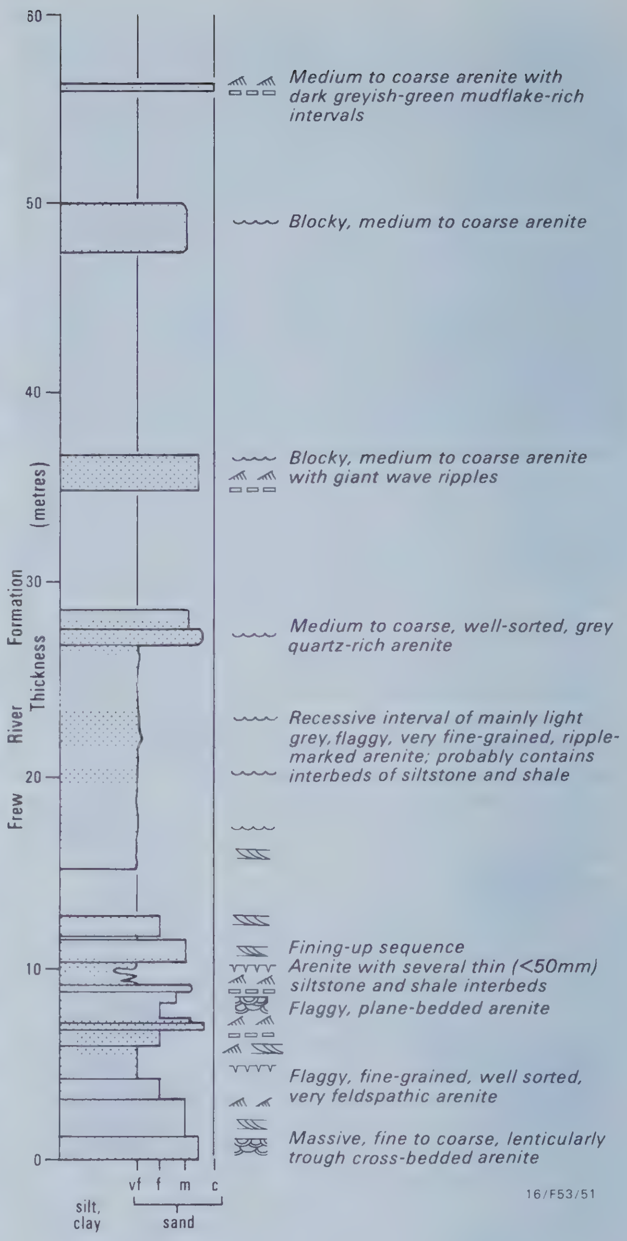

60
50
40
30
20
10
0
Frew River Formation Thickness (metres)
vf f m c
silt, clay
sand
Medium to coarse arenite with dark greyish-green mudflake-rich intervals
Blocky, medium to coarse arenite
Blocky, medium to coarse arenite with giant wave ripples
Medium to coarse, well-sorted, grey quartz-rich arenite
Recessive interval of mainly light grey, flaggy, very fine-grained, ripple-marked arenite; probably contains interbeds of siltstone and shale
Fining-up sequence
Arenite with several thin (<50mm) siltstone and shale interbeds
Flaggy, plane-bedded arenite
Flaggy, fine-grained, well sorted, very feldspathic arenite
Massive, fine to coarse, lenticularly trough cross-bedded arenite
16/F53/51

Fig. 53. Transition beds mapped as basal Frew River Formation in southwest HATCHES CREEK REGION (locality L in Fig. 28; at GR NS026822). Non-outcropping zones are probably laminated shale. For key to symbols see Fig. 30.

uppermost 10 m; and Fig. 53) is about 60 m thick and is characterised by arenites with spectacular wave ripples (Fig. 54). Above the transition about 100 m of shale is overlain by a similar thickness of dolomite, dolomitic siltstone and arenite. The carbonate rocks are finely laminated and in places contain wave and current ripples. The basal 20 m of carbonate shows an upwards gradation from siltstone laminae to wavy algal lamination, possibly formed in part by the fixing of wave ripples by algal mats (Fig. 55). The carbonates include rare thin beds of intraclast-rich dolomite and edgewise dolorudite beds (formed of dolomite intraclasts). Domal stromatolites are present, generally as single domes 0.2–0.3 m high and up to 0.5 m across; their laminae are continuous with adjacent dolomite, indicating that they are pseudocolumnar.

Depositional environments. A low-energy environment is indicated for the Frew River Formation. The lack of coarse clastics may indicate a source area of low relief. The transition from cross-bedded arenite through ripple-marked and also mud-cracked fine arenite at the top of the Coulters Sandstone to wave-rippled arenite in the basal part of the Frew River Formation is interpreted as a brief transgressive episode: the large ripples in this transition probably formed by water waves of rather long period (perhaps 5 to 10 seconds, from Fig. 2–10 in Harms & others, 1982) and are, therefore, more likely to have been generated under open ocean or shelf conditions than in restricted bays or lakes (Komar, 1974). The dolomitic rocks of the formation, with their increasing algal influence upwards, are considered to represent another regressive cycle. The presence of stromatolites indicates deposition in the photic zone, and edgewise intraclast dolorudite beds suggest occasionally emergent conditions with desiccation and reworking of carbonates. The close association of these facies reflect very shallow-water deposition. A sabkha environment,

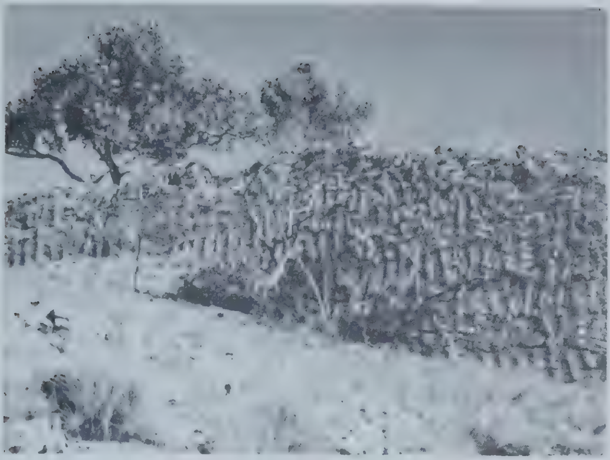


Fig. 54. Large wave ripples preserved on the upper surface of an arenite bed in the lower part of the Frew River Formation in southwest HATCHES CREEK REGION (locality L in Fig. 28, at GR NS029817). Closest part of outcrop is about 5 m high. Ripple wavelength is about 30 cm and amplitude is about 45 mm. (M2696/7)

commonly recognised in Proterozoic dolomitic sequences, is not considered likely as no diagnostic pseudomorphs (e.g., after anhydrite and gypsum) have been observed. A coastal lagoonal environment is favoured to explain the low-energy sedimentation, the fine-lamination, the stromatolites, and the indications of occasional emergence during progradation.

Errolola Sandstone

The 600 m-thick type section of the Errolola Sandstone in southwest HATCHES CREEK REGION (Fig. 28) consists mainly of trough cross-bedded, plane-bedded, and wave and current-rippled arenite. Single trough cross-bed sets 0.2 to 0.5 m thick alternate with much thinner current-rippled beds. The transport directions indicated for the Errolola Sandstone by current ripples and cross-beds are commonly 180 degrees apart (Figs 49f and g), and a bimodal and bipolar palaeocurrent pattern is apparent. Wave ripples include both double-crested and truncated crest types. The uppermost 60 m of the type section is formed of massive conglomeratic arenite and plane-bedded and cross-bedded medium to coarse-grained arenite. At some other localities, the uppermost beds are mudflake-rich ferruginous arenite.

Depositional environments. The bimodal palaeocurrents and alternations of cross-bedded and ripple-marked arenite are considered to indicate a tide-dominated environment. Features such as truncated wave and current ripples, small erosion cliffs, and rare mudcracks show that emergent conditions occurred. A likely environment is a broad intertidal flat similar in many respects to those of the North Sea

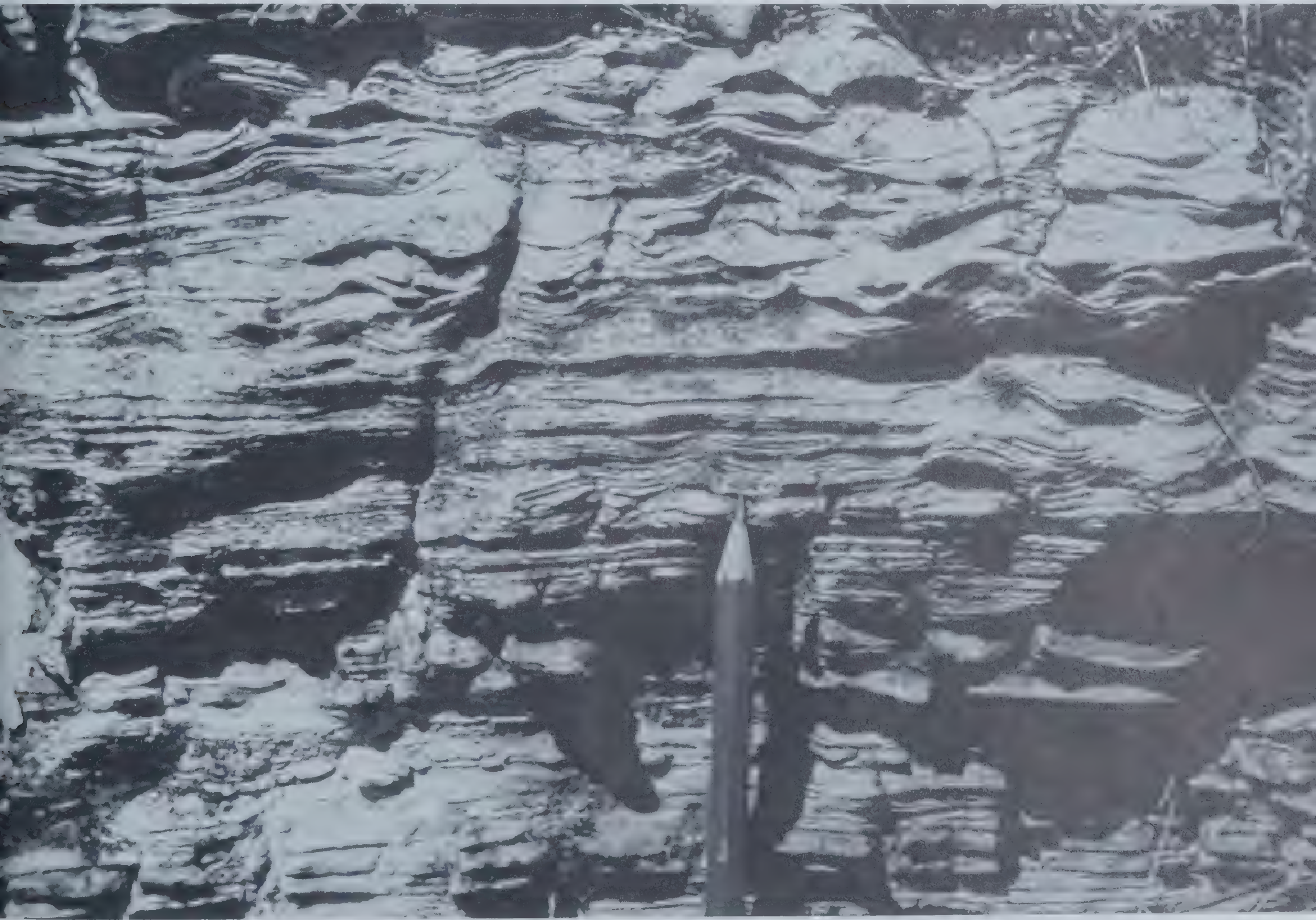


Fig. 55. Algally laminated and algally fixed wave ripples in dololutite of the Frew River Formation in southeast KURUNDI REGION (at GR MS958858). (M2697/12)

described by Reineck & Singh (1980). Although the formation contains very little mudstone, the presence of mudflakes and desiccation cracks indicate that some mud was present.

Alinjabon Sandstone

No detailed sedimentological data are available for the Alinjabon Sandstone, a complex unit (Fig. 56) that appears to be transitional between facies of the Errolola Sandstone and overlying Lennee Creek Formation. Two or three resistant ridge-forming members are present, formed of fine-grained to very coarse and gritty quartz-rich arenites. Two fining-upwards sequences, each 10–15 m thick, were observed in the lowest ridge-forming member in KURUNDI REGION (at locality M in Fig. 28; GR MS992898), both consisting of several beds of lithic and feldspathic arenite grading up from very coarse to gritty through medium to fine-grained.

Depositional environments. In the interval from the top of the Errolola Sandstone to the top of the Alinjabon Sandstone, there are three or more fining-upwards sequences each 100–200 m thick. These are tentatively interpreted as major transgressive cycles, with nearshore shallow-water sands being overlain by deeper water siltstone and shale. The 10–15 m fining upwards sequences within the second major cycle in KURUNDI REGION could have been generated in either a tidal or fluvial environment.

Lennee Creek Formation

The Lennee Creek Formation is composed mainly of poorly exposed siltstone and shale, but also includes some fine-grained, white-weathering arenite with a clayey matrix in its lower half. Arenite near the base shows trough cross-bedding in sets of 0.5–2.0 m thick. Higher in the sequence, arenite is interbedded with shale on a 0.1–0.3 m scale. At one locality in KURUNDI REGION (locality N, Fig. 28; GR MT917028), a graded 0.2 m-thick bed consists of 0.1 m of very fine arenite, with intraclasts of similar arenite, passing up, through parallel laminated and rippled arenite, into laminated siltstone.

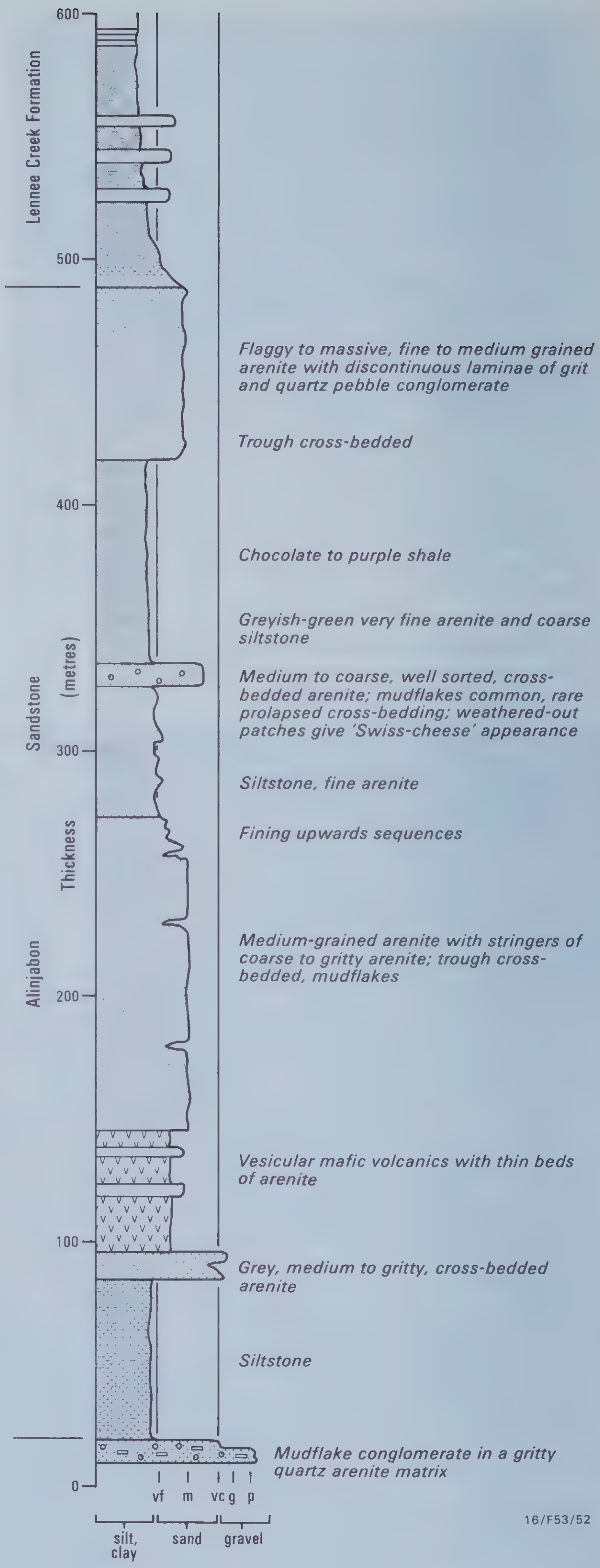
Depositional environment. Taken in conjunction with the Alinjabon Sandstone, the Lennee Creek Formation is interpreted as a shelf shale unit. The water depth was presumably below wave base. The cross-bedded arenite near the base may represent shelf sands. The graded bed described above resembles a Bouma sequence, and may have been generated by turbidity or storm-induced currents.

Canulgerra Sandstone

Arenites in the Canulgerra Sandstone resemble those of the Errolola Sandstone both texturally and in sedimentary structures. Cross-bedding and wave and current ripples (Fig. 57) are common, plane beds, mudcracks, and mudflakes have also been recorded, and ripples with truncated crests and secondary crests are displayed at some localities. On the limited palaeocurrent measurements obtained (Fig. 49g), a bimodal and almost bipolar pattern is evident, very similar to that for the Errolola Sandstone. The Canulgerra Sandstone is interpreted from these features as a shallow-marine, probably tidal flat, deposit.

Vaddingilla Formation and Yaddanilla Sandstone

These units appear to consist mainly of shale and quartz-rich arenite, respectively. Because of their broad similarity to the lower part of the Hanlon Subgroup, they are tentatively interpreted as shallow-marine deposits. No detailed sedimentological observations were made on them.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Lennee Creek Formation
Alinjabon Sandstone Thickness (metres)
Flaggy to massive, fine to medium grained arenite with discontinuous laminae of grit and quartz pebble conglomerate
Trough cross-bedded
Chocolate to purple shale
Greyish-green very fine arenite and coarse siltstone
Medium to coarse, well sorted, cross-bedded arenite; mudflakes common, rare prolapsed cross-bedding; weathered-out patches give 'Swiss-cheese' appearance
Siltstone, fine arenite
Fining upwards sequences
Medium-grained arenite with stringers of coarse to gritty arenite; trough cross-bedded, mudflakes
Vesicular mafic volcanics with thin beds of arenite
Grey, medium to gritty, cross-bedded arenite
Siltstone
Mudflake conglomerate in a gritty quartz arenite matrix
vf
m
vc
g
p
silt, clay
sand
gravel
16/F53/52

Fig. 56. Schematic section of Alinjabon Sandstone. The basal mudflake conglomerate is transitional from the Errolola Sandstone. For key to symbols see Fig. 30.

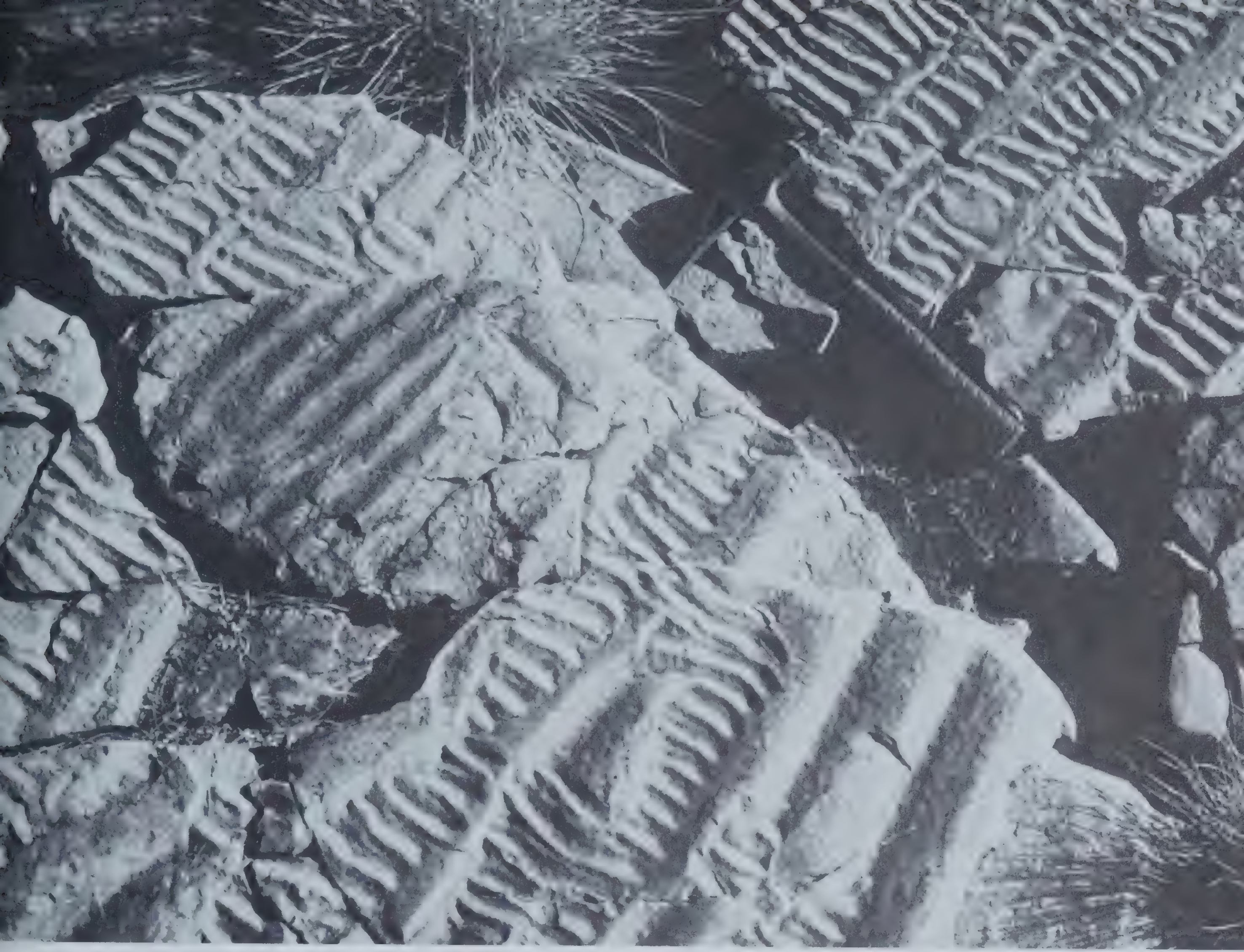


Fig. 57. Two sets of wave ripples in Canulgerra Sandstone, eastern HATCHES CREEK REGION (locality 0, Fig. 28, GR NT632015). The larger ripples, which formed first, are slightly asymmetrical. The ripples in the troughs of the larger ripples were probably formed in very shallow water during low tide on a beach or tidal flat. (M/2697/8)

Petrography and provenance

Modal analyses were carried out on 54 thin sections of representative arenites from the Hatches Creek Group, and the framework grains have been plotted on a QFR diagram (Fig. 58). According to the classification of Pettijohn & others (1973), most of the samples analysed are sublitharenites, some are subarkoses and lithic arenites, but very few are quartz arenites or arkoses.

Sublithic or lithic arenites, completely lacking in feldspar, predominate in the *Rooneys Formation* and *Kurinelli Sandstone*. The only arenites in these two formations with detrital feldspar come from the southeast, in ELKEDRA REGION. In samples from their type-sections, the non-quartz fraction is dominated by sand-sized clay aggregates composed of kaolinite or, less commonly, illite. Some of the clay may be altered feldspar, although the aggregates show no hint of remnant internal structures, such as cleavage or twinning, and do not appear to have the rounded tabular shape of many fresh feldspar grains in the feldspathic arenites. Most of the clay aggregates, therefore, may be altered vitric and lithic grains derived from local volcanoes or rock fragments from sedimentary, volcanic, and low-grade metamorphic sources outside the Davenport province. Many of these grains are compressed and merge with true matrix, suggesting that they were deformed during compaction.

All analysed samples of *Taragan Sandstone* lie in the sublitharenite field. Mineralogically, they are generally more mature than the Kurinelli Sandstone samples, but texturally they are much less mature, ranging from moderately to poorly sorted, medium to coarse, pebbly arenites to very poorly sorted cobble and boulder conglomerates. Grains present include vein quartz, quartzite, chert, mica schist, felsic volcanics, unidentified fine-grained sedimentary or low-grade metamorphic fragments, and clay aggregates similar to those in the Kurinelli Sandstone. A similar range of rock types (apart from clay aggregates) form larger clasts in conglomerate, with vein quartz being the dominant pebble type. The variety of clasts is greatest in southwestern outcrops, where there are also some of fine-grained, light-brown arenite possibly derived from the Kurinelli Sandstone.

Analysed samples of *Unimbra Sandstone* and *Yeeradji Sandstone* are more feldspathic than most underlying arenites. Their assemblage of lithic fragments is similar to that of the Taragan Sandstone.

Three samples of medium to coarse arenites from the *Coulters Sandstone* fall into the sublitharenite field, and have a similar range of rock fragments to the Taragan Sandstone. One sample of very fine-grained arenite from the recessive middle member in the type section is distinctly different: 30% of the grains are clay aggregates, very similar to those in the

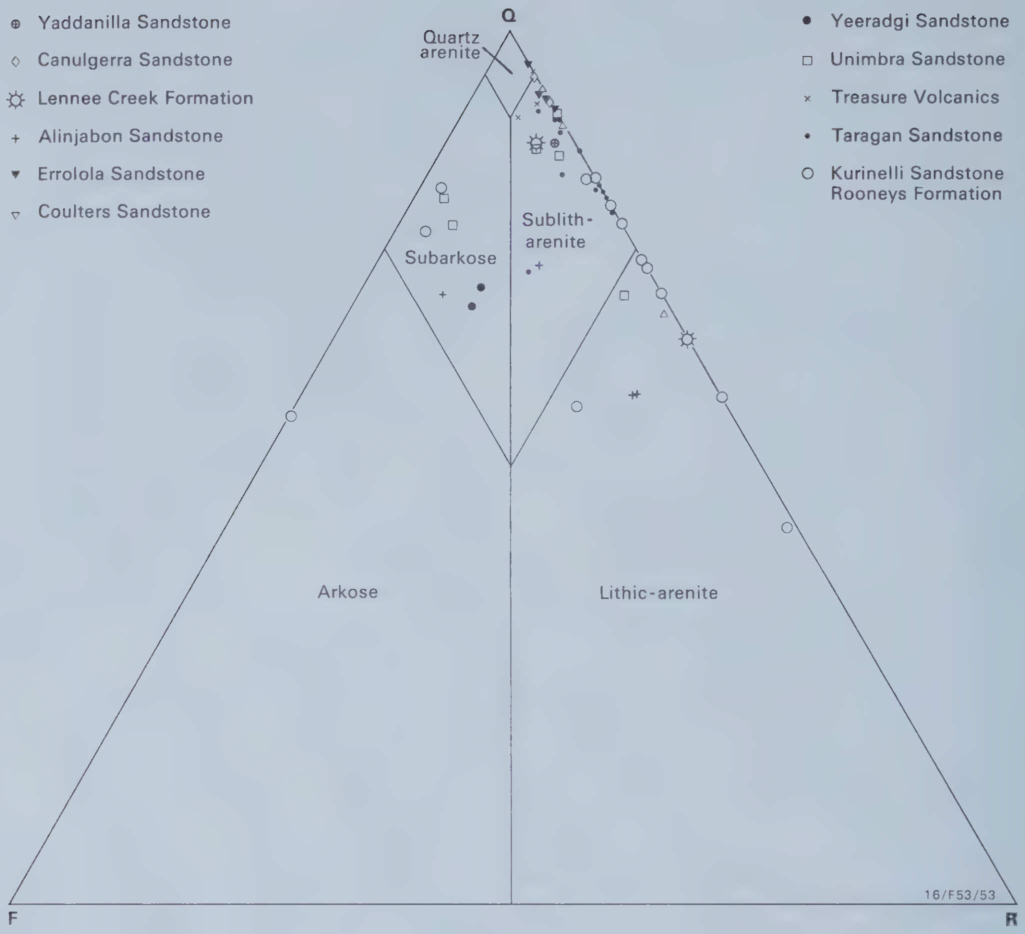


Fig. 58. Arenite modal compositions. Polycrystalline quartz and clay grains are included with lithic fragments (R).

Kurinelli Sandstone. An extrabasinal source for these grains is favoured by the author, although Blake (e.g., in Blake & others, 1986; and Blake & Horsfall, 1987) considers a local volcanogenic origin more likely.

The samples of *Errolola Sandstone* are classified as sublitharenite and quartz arenite. Three samples of *Alinjabon Sandstone*, collected from one 15 m-thick fining-up cycle, range from lithic arenite to arkose. Of the two samples analysed from the *Lennee Creek Formation*, one is a quartz-rich sublitharenite and the other is a lithic arenite.

Discussion

Both marine and fluvial facies have been interpreted for the sedimentary units of the Hatches Creek Group. The subaqueous units, with the exception of the Lennee Creek Formation, were probably deposited in shallow water, and it is clear that subsidence and sedimentation remained in approximate balance for most of Hatches Creek Group time. The presence of bimodal-bipolar palaeocurrents in the Errolola Sandstone is the strongest evidence that shallow marine (tidally influenced) environments are represented. The Unimbra Sandstone and older sedimentary units, with the possible exception of the Rooneys Formation, are considered to be dominantly fluvial, whereas younger sedimentary rocks are dominantly marine. Arenites interpreted as marine are generally more mature, both texturally and mineralogically, than those thought to be fluvial. The Rooneys Formation represents deltaic deposits which have developed at the margin of a sea, or infilled a lake.

The fluvial and volcanic formations reach greater thicknesses than the marine units, and were probably deposited very rapidly. This is consistent with a rift-sag model of basin development, in which syndepositional faulting is implied. Evidence for such faulting is discussed in the following section.

The petrographic results indicate that the Kurinelli Sandstone is generally fairly well sorted, but is strongly lithic, whereas the Taragan Sandstone is not as well sorted, but is mineralogically more mature. This may be due to the Kurinelli Sandstone being more tuffaceous, or derived from finer-grained and less quartz-rich sources. The composition of the Taragan Sandstone and its palaeocurrent measurements indicate a Warramunga Group source area to the southwest. Most sandstones in the Wauchope Subgroup were also derived at least in part, from a Warramunga Group-like source; intrabasinal volcanigenic material may have contributed at times. The source of the largely marine sands in the Hanlon Subgroup is unknown.

Syndepositional tectonism
(AJS)

The Hatches Creek Group is thought to have been deposited in an extensional basin, and hence transfer and normal faults were probably active during sedimentation and volcanism (Bally, 1981; Gibbs, 1984; Etheridge & others, 1984; Etheridge, 1986). Several such faults may be inferred from abrupt changes in sediment thickness which are evident on non-palinspastic isopach maps for the Taragan, Unimbra, Yeeradgi, Coulters, and Errolola Sandstones (Fig. 59). Some, but not all, of the interpreted synsedimentary faults coincide with faults shown on geological maps.

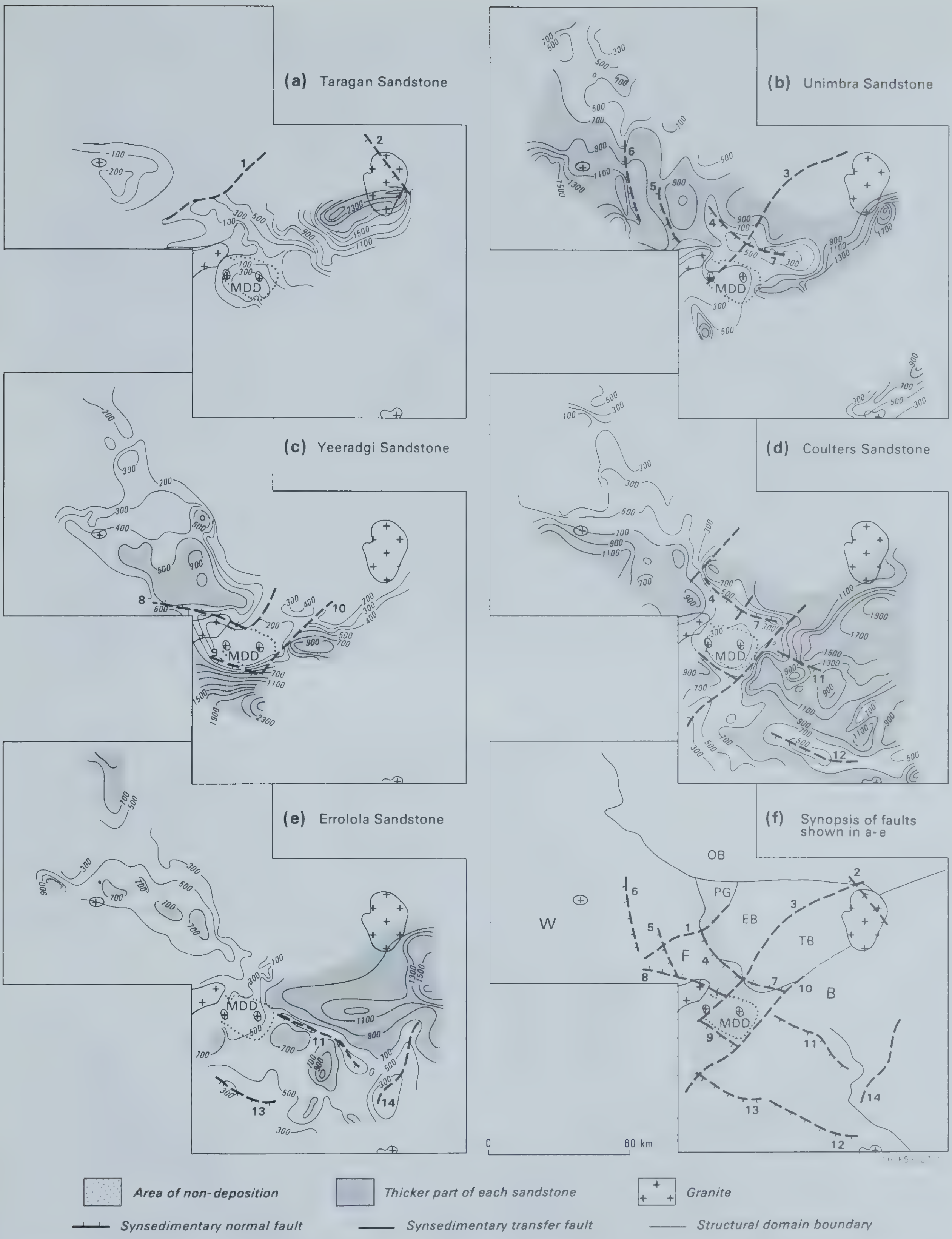


Fig. 59. Isopach maps for Taragan Sandstone, Unimbra Sandstone, Yeeradgi Sandstone, Coulters Sandstone, and Errolola Sandstone of the Hatches Creek Group, and synopsis of synsedimentary faults.

The strongest evidence for a synsedimentary transfer fault is the termination of the Taragan Sandstone along the northwestern margin of the Edmirringee Block (Fig. 59a), where this formation is represented by thick-bedded coarse quartz-pebble conglomerate. Synsedimentary transfer faults are also interpreted along the northwestern and southeastern margins of the Taragan Block, coinciding with closely spaced isopachs for the Unimbra, Yeeradgi, and Coulters Sandstones (Figs

59a, b, c and d). To the west of the Edmirringee Block there may have been a separate basin of Taragan Sandstone. A small equidimensional basin of Taragan Sandstone to the south, coinciding with the Murray Downs Dome, may have been bounded by transfer faults inferred to have been active during deposition of the overlying Unimbra, Yeeradgi and Coulters Sandstone (Figs 59b, c and d).

Synsedimentary normal faults at right angles to the transfer faults may be present where there are narrow bands of relatively thin sediment. The isopach map for the Unimbra Sandstone (Fig. 59b) shows three such bands with north to northwest trends. The most easterly of these, located near the southwestern margin of the Edmirringee Block, continues southeastwards to become coincident with the southwestern margin of the Taragan Block. The dip direction on this inferred normal fault may have been the same as on mapped coincident reverse faults—that is, southwest along the southwestern margin of the Edmirringee Block changing abruptly at a transfer fault to northeast along the southwestern margin of the Taragan Block. The isopachs for the Coulters Sandstone (Fig. 59d) indicate a narrow band of thin sediment at the same location and two similar bands to the southeast, trending northwest. The Errolola Sandstone isopachs (Fig. 59e) show three bands in the south, two trending west-northwest and one trending north-northeast.

In the northeast of the province, an apparent abrupt thinning (based on only two thickness determinations) of the Taragan Sandstone (Fig. 59a) may be caused by a synsedimentary low-angle normal fault dipping southwest.

The isopach maps of the Unimbra, Coulters, and Errolola Sandstones indicate that these units are thickest in the western and eastern parts of the Davenport province and much thinner in the central part. Ranges in thickness from west to east across the province are: Unimbra Sandstone 1600–600–2400 m, Coulters Sandstone 1200–300–2000 m, and Errolola Sandstone 1000–100–1700 m. The thickness variations suggest that a northerly trending central high existed in the Davenport province during deposition of the Hatches Creek Group (Fig. 59f). The central high includes an inferred zone of extension along the southwestern margins of the Edmirringee and Taragan Blocks, separating the two main depositional basins of Taragan Sandstone. The small equidimensional basin of Taragan Sandstone to the south of the Edmirringee Block also lies within this central high.

The isopach maps suggest that during Hatches Creek Group time synsedimentary faulting and a north-trending central high exerted some control on sedimentation. East of the high, the Taragan Sandstone was deposited as a clastic wedge in a northeast-sloping trough or half-graben, probably bounded to the northeast by a southwest-dipping normal fault and to the northwest by a vertical transfer fault. A separate basin of Taragan Sandstone west of the high may have filled a similar but west-sloping trough. At the same time a shallow equidimensional basin was formed near the crest of the high, on the site of the Murray Downs Dome; previously, during deposition of the Kurinelli Sandstone, this had been an area of inland drainage and playa lake deposition (Stewart & Blake, 1986).

In Unimbra Sandstone time, a second northwest-trending transfer fault is thought to have developed on the central high, separating west-dipping normal faults to the west from a northeast-dipping normal fault to the southeast (Fig. 59b). Subsequent movement on the normal faults probably accompanied marine transgressions represented by the Coulters and Errolola Sandstones. Much later, during folding of the Hatches Creek Group, one of the southwest-dipping normal faults was reactivated as the southwest-dipping overthrust margin of the Edmirringee Block, and the northeast-dipping normal fault became the northeast-dipping overthrust margin of the Taragan Block. Likewise, two transfer faults became the strike-slip faults at the margins of the Edmirringee and Taragan Blocks.

The area occupied by the Murray Downs Dome was a shallow basin in Taragan time but became part of a relative high during deposition of the Wauchope Subgroup and Errolola Sandstone. The presence of two small granite outcrops and some greisen within the dome, and pegmatite and tourmalinised sandstone around the margins (Stewart & Blake, 1986) indicate that an extensive granite body may lie at shallow depth below the present ground surface. It is possible, therefore, that the Murray Downs Dome was initiated during deposition of the Unimbra Sandstone by a rising granite mass. Similar doming may have taken place at about the same time just to the west, where a large granite body coincides with an area of non-deposition of the Taragan Sandstone (Fig. 59a).

Deformation

(AJS)

Folding of the Hatches Creek Group occurred in two episodes and was accompanied by reverse faulting. The first folding episode formed the large northwest-trending anticlines and synclines of the Davenport province (e.g., Figs 60, 61, and 1:250 000 geological map). The second episode produced north to northeast-trending folds and reverse faults, and interfered with some of the earlier-formed northwest-trending folds (Fig. 61). The folds generally have moderate plunges (30° to 60°) and face upwards, but a few downward facing folds are present near the centre of the province.

In the Davenport province as a whole, the shortest anticlines are doubly plunging, and are cored by cleaved volcanic rocks of the Ooradidgee and Wauchope Subgroups. Longer anticlines are cored by sedimentary rocks. Synclines are in general longer than anticlines. The volcanics in the cores of the shorter anticlines and domes in the central part of the province probably represent separate volcanic centres which acted as nuclei during folding. The nucleating effect may have resulted from the non-bedded and relatively rigid nature of the volcanic rocks and from the greater thickness of the volcanic edifices compared to the sedimentary rocks, so that the volcanics cleaved, thickened, and domed instead of buckling when shortened.

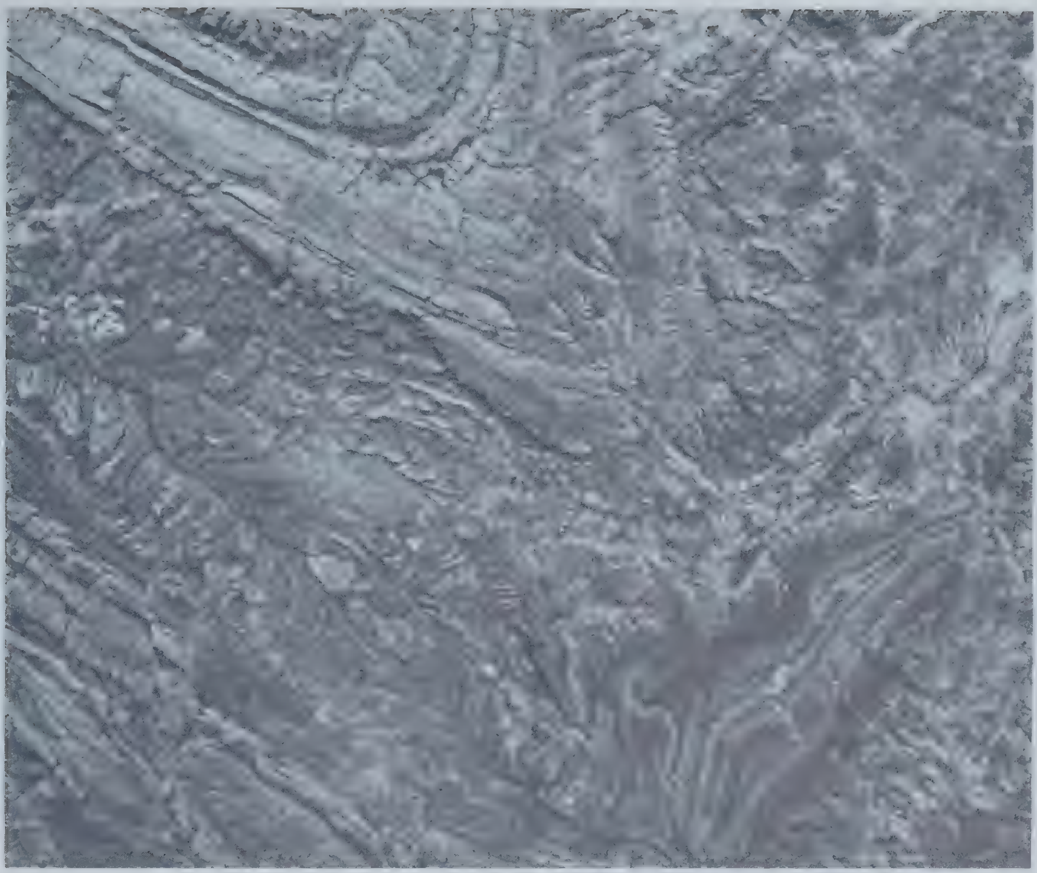
Structural domains

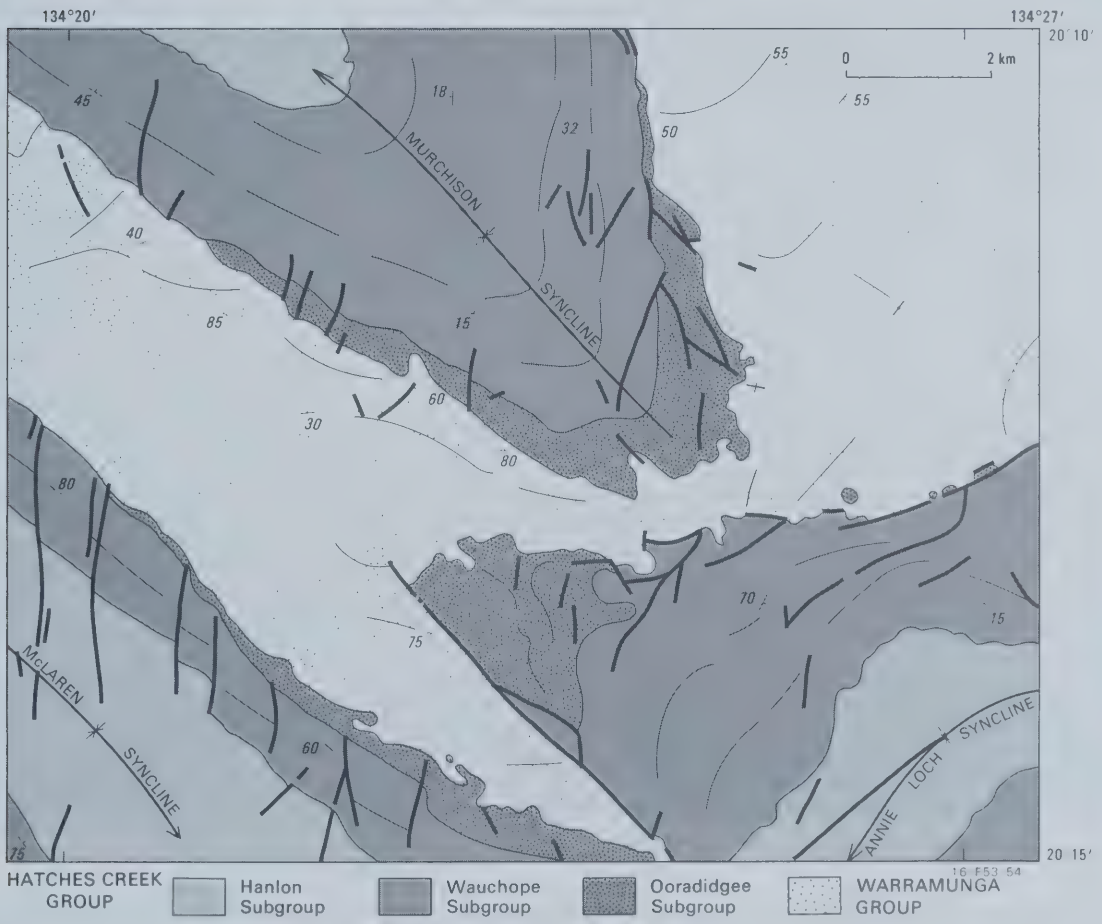
The Davenport province is divided into six structural domains (Fig. 9 and 1:250 000 geological sheet) based on differences in structural trends, times of folding, and lithological make-up.

(1) The **Kelly High**, a poorly exposed area of Warramunga Group and intrusive granite in the northwest. The eastern and southern boundaries are taken to coincide in general with the unconformity between the Warramunga Group and overlying Hatches Creek Group.

(2) The **Ooradidgee Block**, in the north of the province. This domain includes outcrops of the Warramunga Group, granite, and Epenarra Volcanics, and also, on its western side, the Hatches Creek Group in the northeast-trending Annie Loch Syncline. The southern margin of the block is marked by a zone of weakly foliated and quartz-veined Epenarra Volcanics. The Annie Loch Syncline is a fault block which

Fig. 60. Aerial photograph and geological map of part of DEVILS MARBLES REGION showing the northwest-trending Murchison and McLaren Synclines, the northeast-trending Annie Loch Syncline, and the angular unconformity (centre) between the Warramunga Group and overlying Hatches Creek Group. (*Bonney Well* RC9, run 2, photo 0122, CAG 4119, 16.7.1971)




134°20′
134°27′
20°10′
20°15′
0
2 km
55
MURCHISON SYNCLINE
McLAREN SYNCLINE
ANNIE LOCH SYNCLINE
45
18
32
50
55
40
85
15
60
30
80
80
70
15
75
60
75
HATCHES CREEK GROUP
Hanlon Subgroup
Wauchope Subgroup
Ooradidgee Subgroup
WARRAMUNGA GROUP
16/F53/54

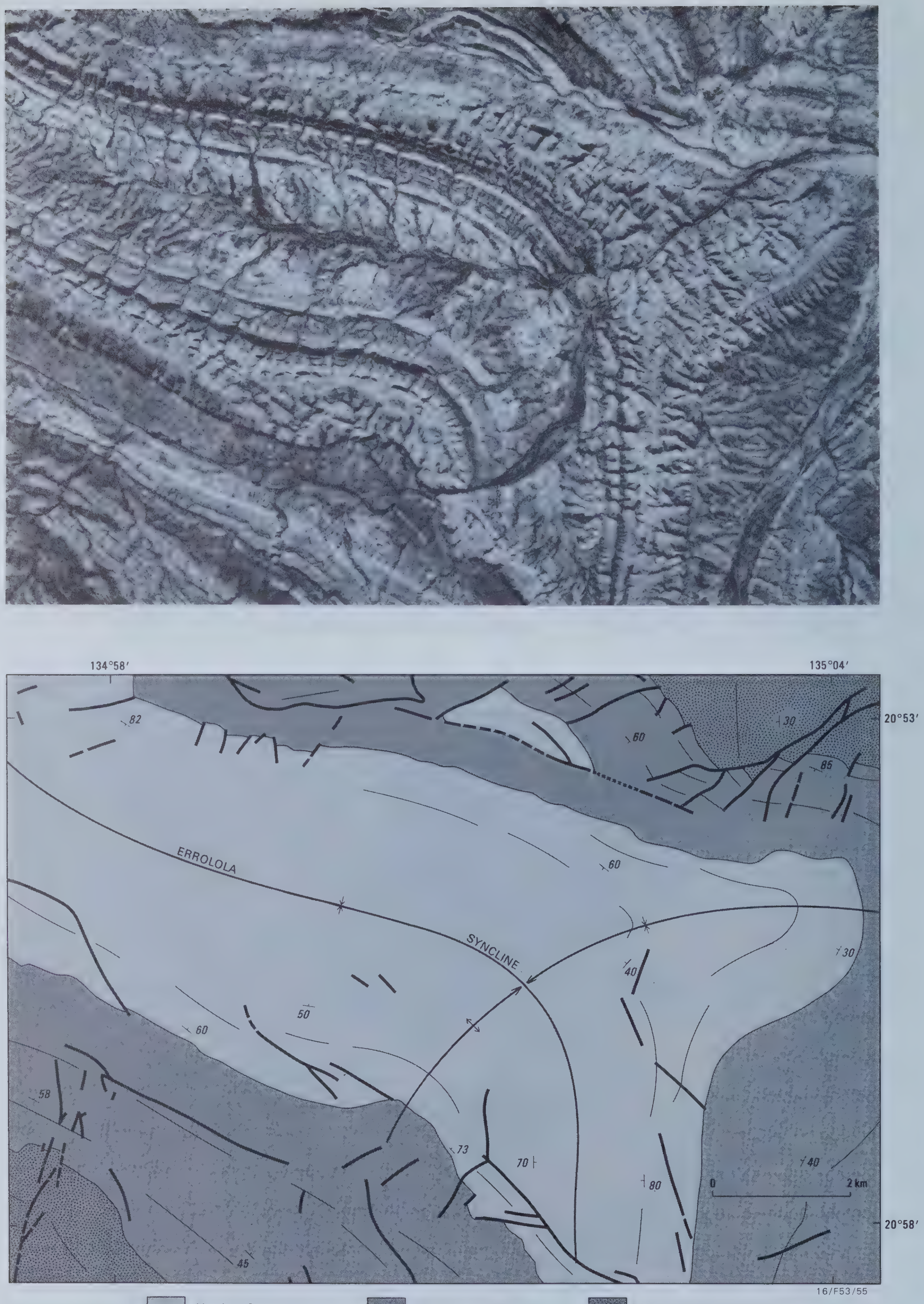


Fig. 61. Aerial photograph and geological map of an area in the central part of the Davenport province (KURUNDI REGION and HATCHES CREEK REGION) showing the sinuous northwest-trending Errolola Syncline bent by a later northeast-trending fold. (*Bonney Well* RC9, run 8, photo 0108, CAG 4118, 9.7.1971)

moved 4 km northwest relative to the adjoining domain (Wauchope Fold Belt; domain 6 — see below) to the southwest; it is bounded to the southwest by a sinistral strike-slip fault, and to the northwest by a thrust or reverse fault.

(3) The **Pingelly Block**, which abuts the Ooradidgee Block to the north. This triangular domain consists predominantly of moderately south-dipping felsic and mafic volcanic rocks of the Ooradidgee Subgroup. It is bounded to the southeast by a dextral strike-slip fault zone marked by shearing and quartz veins, and to the southwest by several steep en echelon reverse faults in the Wauchope Subgroup. The Pingelly Block is essentially a tilted volcanic centre which generally resisted folding except in the southernmost part, where it was squashed between the Wauchope Fold Belt to the southwest and the Edmirringee Block to the southeast, resulting in the formation of a tight southwest-plunging anticline.

(4) The **Edmirringee Block**. This fault-bounded domain, which also consists mainly of the Ooradidgee Subgroup, is characterised by northeast-trending folds and reverse faults. Its southwestern margin is a southwest-dipping reverse fault, 28 km long and with a dip-slip movement of about 2 km, aligned along the recessive Frew River Formation for much of its length. Like the Pingelly Block it is bounded to the southeast by a dextral strike-slip fault marked by shearing and quartz veins. Northeast-oriented reverse faults in the southwest of the Edmirringee Block bend into or join abruptly onto northwest-striking strike-slip faults (tear faults), partly segmenting the domain into smaller blocks. The only northwest-oriented fold in the domain is in the southwest, where a segment of the Bonney Syncline, one of the major folds in the adjoining Wauchope Fold Belt, has been repeated by reverse faulting.

(5) The **Taragan Block**, an oval northeast-oriented block 65 km long and 25 km wide, situated southeast of the Edmirringee Block. This is another domain consisting mainly of the Ooradidgee Subgroup. Except in the southwest, where it includes part of the Bonney Syncline, the Taragan Block is characterised by low to horizontal dips. Estimates from outcrop width and dip information indicate that the Taragan Sandstone of the Ooradidgee Subgroup here is approximately 2600 m thick, about four times as thick as in the Edmirringee Block; the presence of this abnormally thick body of sandstone may explain why the Taragan Block has been affected by comparatively little deformation and appears to have acted as a relatively immobile buttress during tectonism. The Taragan Block is bounded on three sides by a single fault with a U-shaped trace which is 120 km long and open to the northeast. On the northwest side of the domain, this fault has a dextral strike-slip displacement and is marked in places by a subhorizontally striated slickensided breccia. The fault curves progressively south, southeast, and east as a dip-slip high-angle fault, and thence northeasterly as a sinistral strike-slip fault. A cross-section through the southwestern part of the Taragan Block is shown in section CD on the accompanying 1:250 000-scale map.

Lateral offsets in the Bonney Syncline and in a dolerite sill indicate northeastward translation of the Edmirringee Block and Wauchope Fold Belt of 1–2 km relative to the Taragan Block after the northwest-oriented folds had formed.

(6) The **Wauchope Fold Belt**. This domain makes up the remainder of the Davenport province. The western and central parts are characterised by northwest-trending folds and associated reverse faults. These folds range from open to isoclinal, and have steeply inclined axial surfaces with sinuous traces. There are also two north-trending folds in the central part of the domain, about 5 km west of the Taragan Block, in an area where plunges greater than 90° have been measured (i.e., the folds are downward-facing), and one major northeast-oriented fold to the east, near the southeast-bounding fault of the Taragan Block. Axial-surface cleavage fans are largely restricted to tight fold hinges in the central part of the belt, where they are represented by spaced subparallel fractures in arenite beds and slaty cleavage in finer-grained beds (Fig. 62). Fold mullions, formed by the intersection of spaced cleavage and small crumples in arenite, are developed in the hinges of the Alexandra and Errolola Synclines in KURUNDI REGION.

Part of the Wauchope Fold Belt in the southeast of the Davenport province is termed the *George Creek area*. This area consists mainly of Wauchope and Hanlon Subgroups, and is characterised by open to close northeast-trending folds. It is bounded to the southwest by two major northwest-striking faults linked by a northeast-striking fault, but has a gradational boundary to the northwest, in a zone where the major folds trend west-northwest.

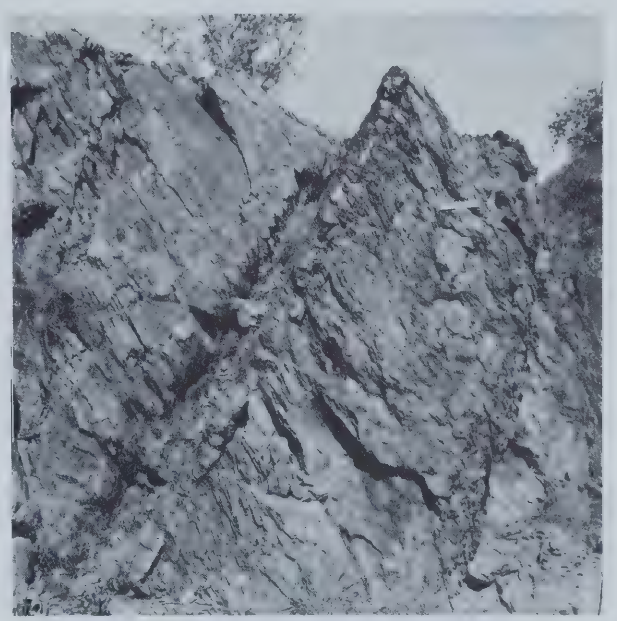


Fig. 62. Axial-surface penetrative cleavage in Frew River Formation, Hatches Creek Group, in the hinge area of the Alexandra Syncline, KURUNDI REGION (at GR MT670070). Scale bar is 150 mm long. (M2477/12)

Fold style

The Wauchope Subgroup and Errolola Sandstone make up a concentrically folded sequence (Stewart, in press) bounded above and below by major detachment zones. Within this sequence some shortening has taken place in tight fold hinges to produce an axial surface cleavage. Formations above (Alinjabon Sandstone and Lennee Creek Formation) and below (Kurinelli Sandstone) the concentrically folded sequence are disharmonically folded on large and medium scales (Figs 63–65). The concentric style of folding means that restorable cross-sections can be drawn, as shown on the accompanying 1:250 000 geological map. In these cross-sections, bed length has been held constant for all formations between upright fold axial surfaces and other areas of horizontal bedding.

Faults

Numerous faults in the Davenport province are interpreted as reverse faults. Almost all of them appear to dip steeply at the surface, but are thought to decrease in dip with increasing depth and change into thrust faults. Several small fault blocks (horses, e.g., Fig. 66) are located along one reverse fault—that forming the boundary between the Edmirringee

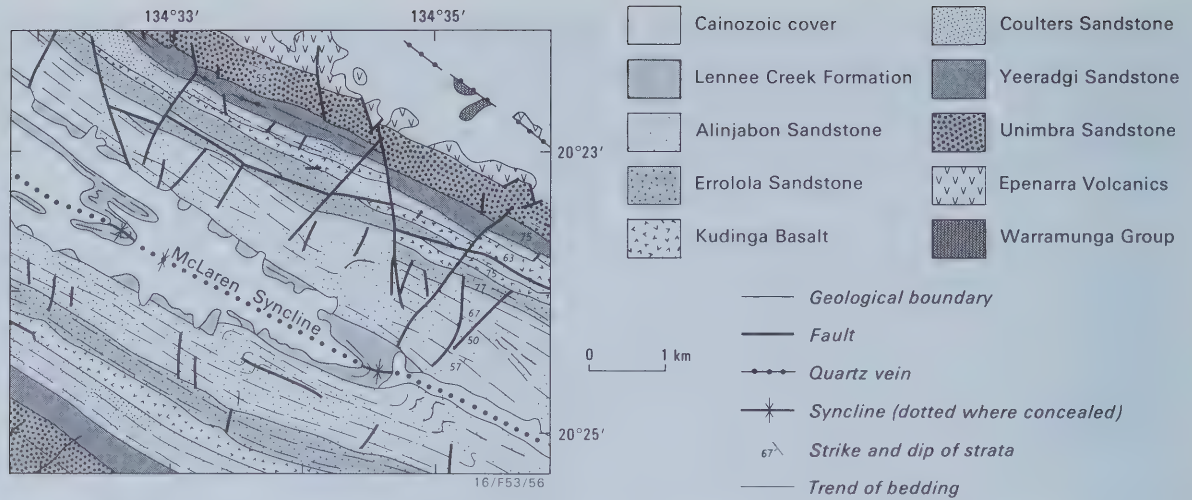


Fig. 63. Part of the McLaren Syncline in KURUNDI REGION, showing disharmonic folds in Alinjabon Sandstone and Lennee Creek Formation above concentrically folded formations of the Hatches Creek Group.

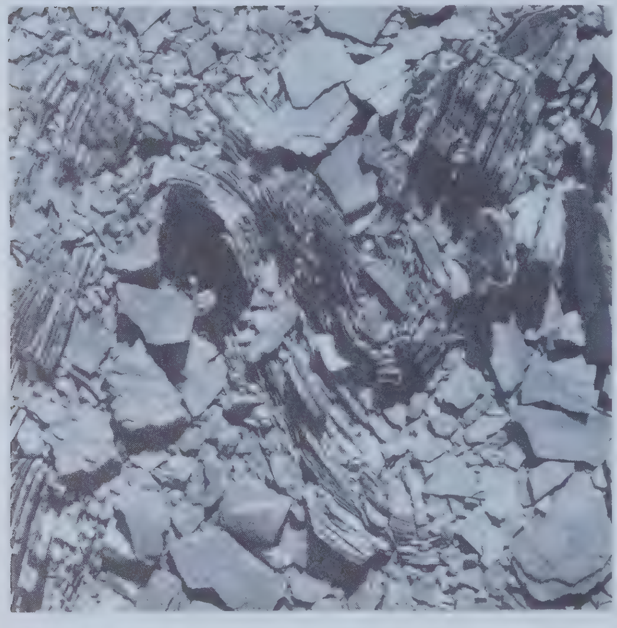


Fig. 64. Small steeply plunging folds in laminated siltstone, Lennee Creek Formation, in the Bonney Syncline, KURUNDI REGION (at GR MT872008). Scale at right is 150 mm long. (M2524/16A)

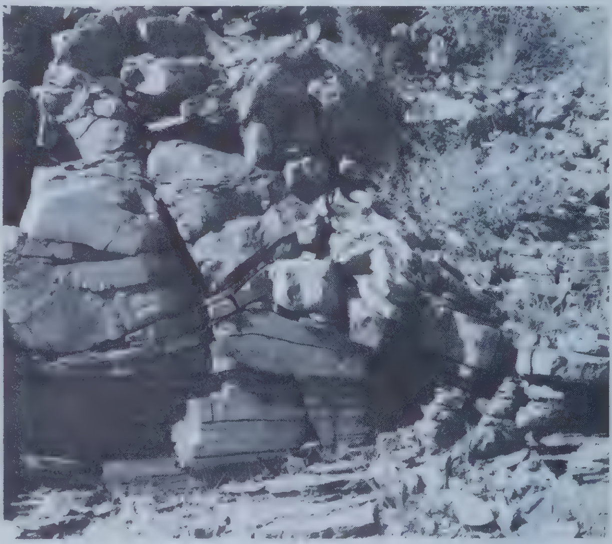


Fig. 65. Small disharmonic fold (amplitude about 25 cm) in Kurinelli Sandstone in crestal area of the Kurundi Anticline, KURUNDI REGION (at GR MT633823). (M2540/16A)

Block and Wauchope Fold Belt. One low-angle thrust fault has been mapped; it forms the northwestern boundary of a triangular window at the crest of the Kurundi Anticline (KURUNDI REGION) in the Wauchope Fold Belt, and puts Ooradidgee Subgroup on top of Wauchope Subgroup. The fault is marked by a spectacular white breccia about 20 m thick. A restorable cross-section through the area (part of cross-section AB on the 1:250 000 map) shows the thrust fault steepening with depth, as it is thought to be an early formed thrust fault that has subsequently been folded.

Superimposed folds

The first episode of folding that affected the Hatches Creek Group formed the northwest-trending large-scale folds of the Wauchope Fold Belt, whereas the second episode resulted in the development of the northeast-oriented folds in the Pingelly, Edmirringee, and Taragan Blocks, and in the George Creek area of the Wauchope Fold Belt. Interference of the

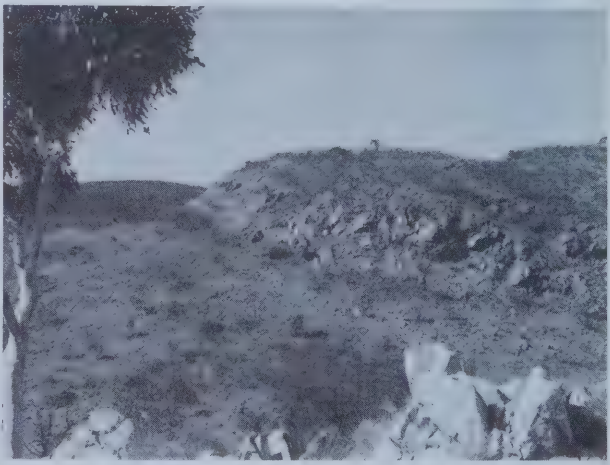


Fig. 66. Fault block (horse) of Alinjabon Sandstone thrust over Lennee Creek Formation in KURUNDI REGION (at GR MT788082). (M2524/1A)

two sets of folds is evident in the north of the George Creek area, where the Wauchope Subgroup shows a pinch-and-swell outcrop pattern indicative of domes and saddles, and near the central part of the Wauchope Fold Belt. Superimposition of the two sets of folds indicates their relative timing. For example, the northwest-trending Skinner Anticline in KURUNDI REGION is crossed by a north-northeast-trending zone of faults and steeply plunging folds which have shortened the anticline by buckling in response to northwest-directed compression. Steeply plunging medium-scale box-folds in the same general area fold a northwest-striking cleavage that is axial-surface to the major folds. To the east a penetrative cleavage that is axial-surface to the Skinner Anticline is folded by two north-trending folds. This cleavage is overprinted by a second (spaced) cleavage, which is axial-surface to the north-trending folds. Beds in the hinge zone of the north-trending anticline are cut by both cleavages.

Deformation history

Deformation of the Hatches Creek Group began with concentric folding about generally northwest-trending axes, accompanied by reverse faulting. In places, such as in the central part of the province, possible pre-existing synsedimentary normal faults were reactivated as reverse faults during this early (first) episode of deformation. Restorable cross-sections indicate a detachment surface in the Kurinelli Sandstone of the Ooradidgee Subgroup, but siltstone and claystone are rare and no evaporite layers are known at this level. Furthermore, units underlying the Kurinelli Sandstone, such as the Epenarra and Edmirringee Volcanics, are exposed in the cores of anticlines, and the faulting and folding are believed to have affected the Warramunga Group as well as the Hatches Creek Group. Hence there is no regional decollement beneath the Wauchope Subgroup. Bends in the axial surfaces of the major folds may have been caused by strike-slip movement along pre-existing northeast-trending transfer faults. Overall northeast-southwest shortening during the first folding was about 30%.

The second episode of deformation formed (a) the northeast to north-northeast-trending folds in the Edmirringee Block and George Creek area of the Wauchope Fold Belt; (b) the northeast-striking thrust faults and northwest-striking strike-slip faults in the Edmirringee Block; (c) the southwest-plunging anticline in the south of the Pingelly Block; (d) the southwest-plunging Annie Loch Syncline in the west of the Ooradidgee Block; (e) the north-trending folds 5 km west of the Taragan Block; (f) the steeply plunging downward-facing folds a few kilometres farther west; (g) the sinuous bends in the axial surfaces of the major northwest-trending folds; and (h) the domes and saddles in the east and southeast of the Davenport province. It also buckled the Skinner Anticline along its length and folded earlier cleavage.

Regional metamorphism
(DHB)

The Hatches Creek Group has been regionally metamorphosed to mainly greenschist facies. This metamorphism is thought to have accompanied the deformation of the group, and it predates emplacement of the Elkedra Granite, which probably took place around 1660 Ma.

Greenschist facies regional metamorphism is indicated by the following evidence:

(1) In the sedimentary rocks, primary depositional and early diagenetic features are generally well preserved. However, most arenites have a quartz-overgrowth cement which may in part be a metamorphic feature, and a cleavage is present in places, especially in siltstone and fine-grained rocks. Metamorphic white mica and greenish brown biotite occur in the matrix of many arenites and in siltstones.

(2) Felsic tuffs are commonly cleaved (e.g., Fig. 14) and typically contain metamorphic white mica and either biotite or chlorite.

(3) Felsic lava and ignimbrite, and also associated granophyre sills, have phenocrysts of (a) albite replacing originally more calcic plagioclase, (b) quartz showing undulose extinction, and (c) ferromagnesian minerals pseudomorphed mainly by chlorite or biotite. They also generally have metamorphic muscovite, biotite and/or chlorite in the groundmass.

(4) Basaltic lavas and the dolerite/gabbro sills within the Hatches Creek Group characteristically have some igneous textures preserved, but most original plagioclase and pyroxene are partly or completely altered. Albite, actinolite, hornblende, epidote, chlorite, biotite, white mica, and leucoxene are present as secondary minerals.

Lower and higher grade rocks are present locally. For example, in the Edmirringee Block some basalt of the Edmirringee Volcanics has prehnite and pumpellyite, indicative of the subgreenschist facies, and on the east side of the Mia Mia Dome brown biotite and porphyroblastic dark green amphibole present in recrystallised ignimbrite of the Newlands Volcanics show that metamorphism probably reached amphibolite facies.

A subsequent alteration event, postdating the deformation and regional metamorphism, may have affected the Davenport province. This is suggested from Rb–Sr whole-rock data for felsic volcanics in the Ooradigee and Wauchope Subgroups tentatively interpreted by Blake & Page (in press) as indicating region-wide hydrothermal alteration at 1645 ± 44 Ma.

PROTEROZOIC INTRUSIONS
(DHB)

Intrusive rocks of Proterozoic age are exposed in several parts of the Davenport province. In the north, the Warramunga Group is intruded by the Hill of Leaders Granite, unnamed granite, unnamed feldspar porphyry, and probably dolerite, all of which are considered to predate the Hatches Creek Group. To the south, granophyre and dolerite/gabbro form high-level subvolcanic sills and other intrusive bodies within the Ooradidgee Subgroup and lower part of the Wauchope Subgroup; these intrusions are probably comagmatic with volcanics in the subgroups. Younger intrusions include plutons of Elkedra Granite, Devils Marbles Granite and unnamed granite, which were emplaced after the Hatches Creek Group had been folded; and probably also include dykes of lamprophyre cutting Hill of Leaders Granite in the Mosquito Creek tungsten field. Details of the intrusive units are given in Table 2.

The **Hill of Leaders Granite** crops out extensively east of the Murchison Range in the north of the region, forming tors, spheroidal boulders, and low whalebacks. It consists mainly of grey medium to coarse-grained muscovite–biotite and biotite granite with prominent feldspar phenocrysts and numerous fine-grained micaceous xenoliths. In the Mosquito Creek tungsten field, the granite is cut by wolframite and scheelite-bearing quartz veins, some of which are bounded by greisen. A minimum age for the granite is given by a K–Ar biotite date of 1400 Ma (Hurley & others, 1961). However,

TABLE 2. DETAILS OF PROTEROZOIC INTRUSIONS, DAVENPORT PROVINCE.

Unit and map symbol	*Rock types*	*Relationships*
Lamprophyre dykes lp	Massive to foliated fine-grained lamprophyre consisting of biotite, microcline and accessory apatite (abundant), zircon, muscovite, and quartz.	Intrude Hill of Leaders Granite in Mosquito Creek tungsten field.
Unnamed younger granitic rocks Ᵽgu	Leucocratic medium to coarse-grained muscovite–biotite granite and minor greisen and pegmatite veins (in Mia Mia Dome and Murray Downs Dome); fine to coarse-grained muscovite–biotite granite and biotite granite (in NE of Taragan Block); porphyritic fine-grained granodiorite, leucocratic microgranite and weakly to strongly foliated graphic biotite granite (in far south).	Intrude formations of Ooradidgee Subgroup, Hatches Creek Group.
Devils Marbles Granite Ᵽgd	Medium to coarse-grained granite with perthitic microcline (partly as phenocrysts), subhedral oligoclase, and quartz in about equal amounts, biotite, subordinate muscovite, accessory opaque minerals, fluorite, sphene, zircon, and apatite; and secondary chlorite and epidote; minor greisen.	Intrudes Kurinelli Sandstone and Taragan Sandstone of Ooradidgee Subgroup, and Unimbra Sandstone and Yeeradgi Sandstone of Wauchope Subgroup, Hatches Creek Group.
Elkedra Granite Ᵽge	Even-grained to slightly megacrystic leucogranite; minor medium-grained tourmaline granite, greisen, aplite, tourmaline–quartz–feldspar pegmatite, quartz–tourmaline veins.	Intrudes Rooneys Formation of Ooradidgee Subgroup, Hatches Creek Group.
Felsic sills Ᵽgy	Dacitic to rhyolitic granophyre and minor microgranite: pale to dark grey, pink, or maroon; commonly spherulitic, less commonly miarolitic at margins of intrusions; foliated/cleaved in southeast; generally with sparse to abundant phenocrysts of plagioclase (now albite) ± microcline (rare) ± quartz (rare) ± biotite (mostly altered) ± opaque minerals ± pseudomorphed amphibole or pyroxene, together with irregular fine-grained mafic clots (mainly biotite and/or chlorite + opaques ± epidote) in fine to very fine-grained micrographic or microgranitic groundmass; accessory minerals include apatite, zircon, and sparse sulphides; secondary minerals include chlorite, greenish brown biotite, epidote, white mica, hematite, calcite, and rare greenish brown amphibole. Many intrusions are well jointed at margins, parallel to contacts; some have aureoles of hornfels up to a few metres thick.	Intrude Ooradidgee Subgroup and lower part of Wauchope Subgroup of Hatches Creek Group; intruded by Elkedra Granite. May intrude unnamed older granite in north KURUNDI REGION.
Mafic sills Ᵽd	Fine-grained dolerite ranging to coarse gabbro; dark grey to greenish grey where little weathered; rarely porphyritic; commonly ophitic; generally altered, but primary pyroxene (mainly augite) and calcic plagioclase (An 40–80) preserved locally; interstitial micrographic quartz and alkali feldspar and minor sulphides (pyrite and/or chalcopyrite) commonly present; secondary minerals include epidote, chlorite, albite, biotite, white mica, and actinolitic amphibole; foliated in far southeast.	Intrude formations of Ooradidgee Subgroup and lower part of the Wauchope Subgroup, Hatches Creek Group.
Dolerite dykes dl	Range from less than one metre to several metres in thickness; consist of dark grey, medium to fine-grained dolerite formed mainly of plagioclase laths (generally altered), partly ophitic clinopyroxene, uralitic amphibole, opaque oxide, and chlorite.	Intrude Hill of Leaders Granite and unnamed granite, overlain by Epenarra Volcanics, Hatches Creek Group, in KURUNDI REGION.
Unnamed feldspar porphyry Ᵽo	Feldspar porphyry: generally deeply weathered, bleached (white) to iron-stained; with abundant small phenocrysts of altered feldspar ± quartz in fine-grained groundmass (now mostly clay); massive to locally cleaved/schistose; with inclusions of folded Warramunga Group rocks at GR MT470660 (DEVILS MARBLES REGION).	Intrudes Warramunga Group; overlain by Epenarra Volcanics and Unimbra Sandstone, Hatches Creek Group.

TABLE 2. (continued)

Unit and map symbol		*Rock types*	*Relationships*
Unnamed older granite	Ꝑg	Leucocratic granite: pink or pale grey; medium to coarse-grained; even-grained to porphyritic; typically consists of microcline, subordinate oligoclase, quartz and minor partly chloritised biotite ± muscovite.	Intrudes Warramunga Group: cut by dolerite dykes and probably, in KURUNDI REGION, by granophyre; overlain by Hatches Creek Group (Epenarra Volcanics).
Hill of Leaders Granite	Ꝑgh	Porphyritic and minor even-grained xenolithic muscovite–biotite and biotite granite; sparse aplite, greisen. Granite: grey; mostly with abundant feldspar phenocrysts up to 5 cm across (plagioclase and subordinate microcline) and fine-grained mica-rich xenoliths in medium to coarse-grained groundmass consisting of about equal amounts of subhedral oligoclase (weakly zoned), anhedral perthitic microcline, and strained quartz, 10–15% biotite, subordinate muscovite, and accessory and secondary apatite, chlorite, epidote, sericite, and zircon; tourmaline is present in greisen, in some xenoliths and on joint surfaces (commonly as stellate clusters).	Intrudes Warramunga Group; cut by dykes of dolerite and lamprophyre. Not seen in contact with Hatches Creek Group.

the Hill of Leaders Granite is thought to be comparable in age to the porphyritic Cabbage Gum Granite in *Tennant Creek* to the north, which has a U-Pb zircon age of 1846 ± 8 Ma (Black, 1984).

Unnamed granite probably similar in age to the Hill of Leaders Granite is exposed (a) to the east and north of this granite; (b) on the west side of a prominent ridge-forming quartz vein between the Hill of Leaders Granite and the Murchison Range; and (c) to the west of this range, where the BMR aeromagnetic map of *Bonney Well* indicates the presence of two substantial granite bodies largely concealed beneath Cainozoic sediments (see Proterozoic Geology and Structure map on the 1:250 000 geological sheet).

Dolerite forms dykes, some of which are several metres wide, intruding the Hill of Leaders Granite and unnamed granite in the north of the Davenport province. As one of the dolerite dykes cutting unnamed granite in KURUNDI REGION is overlain by Epenarra Volcanics (at GR MT784367), all are tentatively inferred to predate the Hatches Creek Group.

Irregular bodies of **unnamed feldspar porphyry** intrude the Warramunga Group and are overlain by the Epenarra Volcanics and Unimbra Sandstone of the Hatches Creek Group in the northwest of the Davenport province. The porphyry has small phenocrysts of altered feldspar and commonly minor quartz in a fine-grained groundmass, and is generally intensely weathered to a white or iron-stained clayey rock. In places the porphyry is strongly cleaved, as at the Munadgee uranium prospect (KURUNDI REGION, GR MT544490), where autunite and torbernite occur in cross-cutting quartz veins. Inclusions of folded Warramunga Group rocks in porphyry in DEVILS MARBLES REGION (at GR MT470660) show that the porphyry postdates the early folding of the Warramunga Group. Some outcrops mapped as intrusive feldspar porphyry may be altered felsic volcanics belonging to either the Warramunga Group or the Epenarra Volcanics of the Ooradidgee Subgroup. The intrusive porphyry is possibly related genetically to the Epenarra Volcanics.

The **felsic and mafic sills** within the Hatches Creek Group range in thickness from a few metres to several hundred metres. There are also a few associated dykes and irregular bodies which may be feeders either for the sills or for nearby extrusives. The intrusions have chilled margins, and are commonly bounded by contact aureoles of hornfels up to a few metres thick. They predate folding of the Hatches Creek Group, and appear to be chemically and mineralogically identical to the felsic and mafic volcanics in the Hatches Creek Group. Hence they are considered to be intrusive equivalents of these volcanics. At the few localities where mafic and felsic sills have been seen in contact with each other, there is a diffuse zone several metres wide of heterogeneous dioritic hybrid rocks. Deeply weathered and lateritised felsic and mafic sills are often difficult to tell apart.

The felsic sills are formed of porphyritic dacitic to rhyolitic granophyre (Fig. 67) and minor microgranite. Typical exposures consist of gently undulating terrain with small, partly rounded, smooth boulders that have thin pale weathered crusts. Some felsic sills have bulbous lower contacts indicative of intrusion into unconsolidated sediments. Many have small miarolitic cavities; few have any xenoliths. None of the felsic sills are known to be mineralised, although hematite–magnetite–quartz veins, presumably with some gold, are spatially associated with deeply weathered phenocryst-rich granophyre at the Cairns gold prospect in HATCHES CREEK REGION (at GR NT021108).

Mafic sills are formed of dolerite and gabbro in which interstitial micrographic quartz and alkali feldspar are commonly present. They are generally more recessive than the felsic sills, typical exposures consisting of low bouldery mounds in general depressions. Abrupt internal variations in texture and composition and the presence of thin screens of country rock show that many of the mafic sills are multiple intrusions. In the Hatches Creek tungsten field, the dolerite and gabbro bodies, together with the granophyre intrusions, were grouped together as the Pedlar Gabbro by Ryan (1961), who regarded the granophyre as a late-stage differentiate of the gabbro. However, the absence or scarcity of sills intermediate in composition shows that the mafic and felsic magmas probably came from separate sources. Some of the mafic intrusions here are cut by quartz veins with tungsten and copper minerals. To the north, especially near the abandoned Kurinelli Outstation, several of the mafic intrusions are cut by auriferous quartz veins.

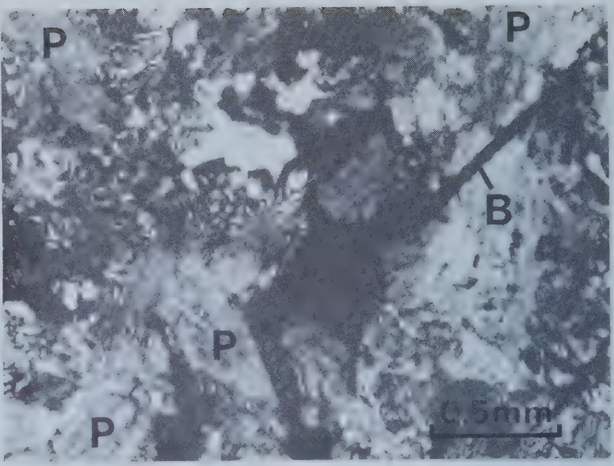


Fig. 67. Photomicrograph of rhyolitic granophyre (73.3% SiO_2). Small phenocrysts of sodic plagioclase (P), biotite (B, pseudomorphed by chlorite and opaque material), and opaque oxide lie in a partly micrographic groundmass of quartz and alkali feldspar; crossed polarisers; sample No. 81111451A; from GR NT260051, HATCHES CREEK REGION. (M2766/12)

The **Elkedra Granite** intrudes the Rooneys Formation of the Hatches Creek Group and granophyre and is overlain by flat-lying Cambrian strata (Fig. 68) in the far southeast of the Davenport province. The main rock type is medium to coarse-grained leucogranite with muscovite and small amounts of biotite. Intrusive roof and side contacts exposed near the Juggler tungsten mine show that the pluton was intruded after the Hatches Creek Group had been folded. Contact metamorphic rocks, including spotted mica schist

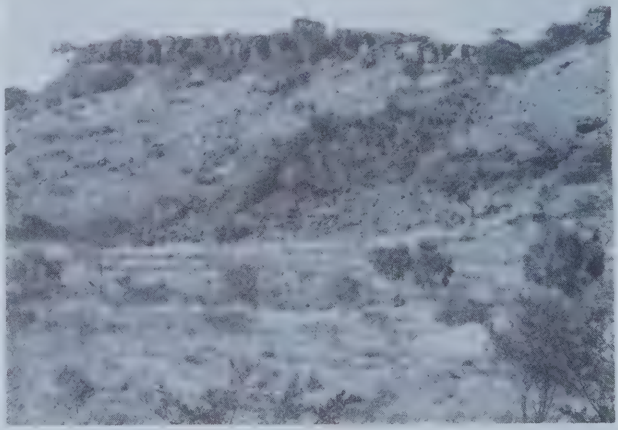


Fig. 68. Flat-lying Cambrian strata about 10 m thick capping Elkedra Granite in southeast ELKEDRA REGION. (M2523/24)

and hornfels, occur within about 100 m of the pluton. The granite does not appear to contain xenoliths, or to be significantly deformed or recrystallised, unlike a body of foliated biotite granite exposed 5 km to the southeast. At the Juggler mine, the Elkedra Granite is cut by wolframite-bearing quartz–tourmaline veins bordered by greisen (Fig. 69). A K–Ar biotite age of 1430 Ma was determined for the granite by Hurley & others (1961), but Rb–Sr data indicate that the granite was probably emplaced somewhat earlier, at around 1660 Ma (Blake & Page, in press).

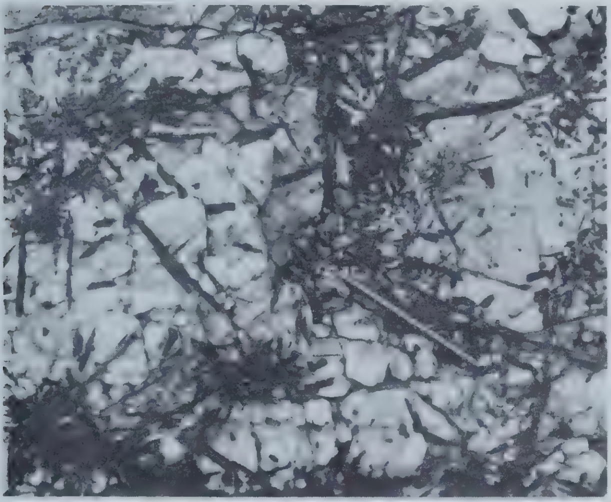


Fig. 69. Stellate clusters of tourmaline crystals in wolframite-bearing quartz vein cutting Elkedra Granite at the Juggler tungsten mine, ELKEDRA REGION (at GR NS490248). (M2523/20)

The **Devils Marbles Granite** forms the Devils Marbles on the Stuart Highway (Fig. 70), 9 km north of Wauchope. Gravity data suggest that the exposed granite is part of a steep-sided pluton that is more extensive at shallow depth (Hone, 1983). Pale pinkish muscovite–biotite granite with phenocrysts of perthitic microcline is the predominant rock type. The granite intrudes the Hatches Creek Group in the core of the Devils Marbles Anticline; and is thought to postdate folding of this group. It is probably older than the K–Ar biotite age of 1540 Ma reported by Hurley & others (1961), and may be similar in age to the Elkedra Granite. The mineralisation in the Wauchope tungsten field to the southeast of the pluton may be genetically related to the Devils Marbles Granite. Tungsten-bearing quartz veins occur within the granite at GR MT256258.

Unnamed granitic rocks which probably post-date folding of the Hatches Creek Group are exposed in several parts of the province. Pink medium to coarse-grained leucogranite comparable to the Elkedra Granite intrudes Kurinelli Sandstone, Edmirringee Volcanics, and probably Unimbra Sandstone in the northwest of the Murray Downs Dome, and Mia Mia Volcanics in the Mia Mia Dome. Gravity and airborne magnetic data indicate that isolated exposures of unnamed granite in the northern central part of HATCHES CREEK REGION are part of an extensive body largely concealed by Cainozoic sediments. Several plutons may be present here as the exposed rocks range in texture from fine to coarse-grained and even-grained to porphyritic, and in composition from biotite granite to leucocratic muscovite granite. They intrude Rooneys Formation, Kurinelli Sandstone, and possibly Taragan Sandstone. In the southeast of ELKEDRA REGION, the Rooneys Formation is intruded by unnamed porphyritic fine-grained granodiorite and possibly also by leucocratic microgranite. The latter rock consists of an equigranular mosaic of quartz and microcline, with minor weakly aligned muscovite and biotite; it is cut by veins of granite probably emanating from nearby Elkedra Granite, and could be basement underlying, rather than intruding, the Hatches Creek Group.

Unnamed biotite granite exposed southeast of the Elkedra Granite is weakly to strongly foliated. It is a pink, medium-grained rock with a graphic texture, and has small dark xenoliths. It appears to intrude the Rooneys Formation but, as it is foliated, it was probably emplaced before the Hatches Creek Group was deformed and hence is probably older than the Elkedra Granite. The only sample chemically analysed plots with the granophyre sills and felsic volcanics of the Hatches Creek Group on variation diagrams.

Irregular dykes of **lamprophyre** about 2 m thick intrude the Hill of Leaders Granite in the Mosquito Creek tungsten field. The lamprophyre consists mainly of biotite and feldspar. It is probably comparable in age to petrographically similar lamprophyre intruding the Warramunga Group near Tennant Creek and dated by Black (1977) at about 1670 Ma (Rb–Sr whole-rock isochron).

GEOCHEMISTRY OF IGNEOUS ROCKS

(DHB)

Representative samples of igneous rocks exposed in the Davenport province were collected in the field for petrographic, geochemical and geochronological laboratory studies. Following examination of thin-sections, 170 samples that appeared to be least altered were chemically analysed for major and trace elements. Although all analysed samples have been affected to some extent by weathering, low-grade metamorphism, hydrothermal alteration and/or metasomatism, most are thought to closely reflect their original igneous compositions. A description of the analytical methods used is given in the Appendix, and chemical analyses are listed in a microfiche at the back of the Bulletin. The number of samples analysed per rock unit, together with their general location and range in silica content, are given in Table 3. Variation diagrams for selected major and trace elements are shown in Figs 72 and 73.

Geochemical features

The chemical analyses show that the igneous rocks of the Davenport province are markedly bimodal with respect to silica content (Fig. 71). Of the 170 rocks analysed, 124 contain more than 63% SiO_2 and are classed as felsic, whereas 43 have less than 57% SiO_2 and are termed mafic. Only three have silica contents between 57 and 63%; two of these are samples of lamprophyre and the other is a highly altered sample from the Mia Mia Volcanics. The significance of the secondary peak for the felsic rocks at 63–65% SiO_2 is not clear; it may be due to sampling bias. The bimodal distribution indicates that the Davenport province was probably in a region of general crustal extension during the igneous activity.

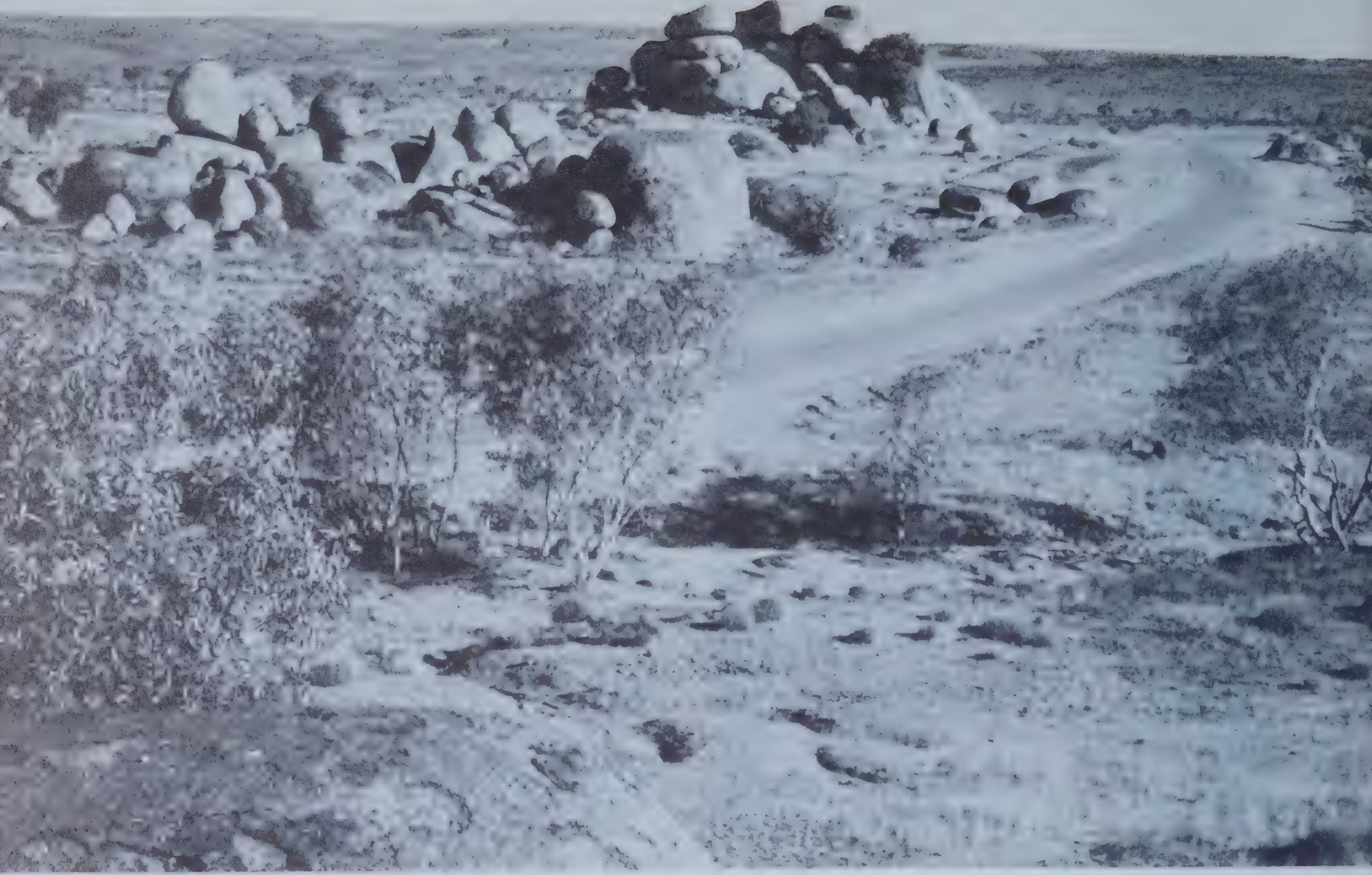


Fig. 70. The Devils Marbles, formed of Devils Marble Granite, on the Stuart Highway in DEVILS MARBLES REGION. The geomorphology of the Devils Marbles is discussed by Twidale (1980). (M2695/25A)

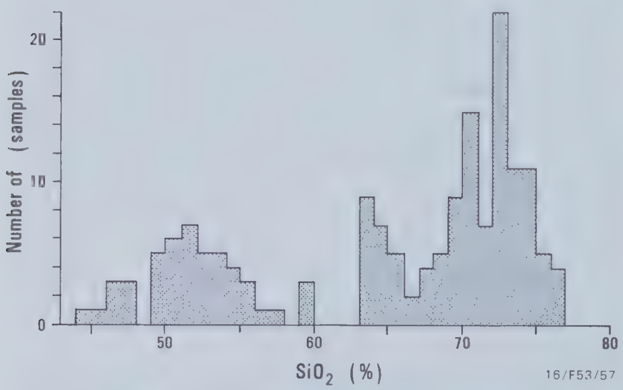


Fig. 71. Histogram of silica contents for chemically analysed igneous rocks from the Davenport province.

Felsic rocks

The felsic igneous rocks of the Davenport province, those with more than 63% SiO_2, are potassic, typically having between 3 and 7% K_2O and K_2O/Na_2O values greater than 1.5.

The nine analysed samples from the **Warramunga Group** show well-defined trends for TiO_2, Al_2O_3, CaO, P_2O_5, Sr, Zr, Y, Nb, V, and Cr plotted against SiO_2 (e.g., Fig. 72). They closely resemble in their chemistry other felsic volcanics of similar age (around 1870 Ma), and also comagmatic granites, exposed in northern Australia: for example, the Leichhardt Volcanics and Kalkadoon Granite of the Mount Isa Inlier (e.g., Bultitude & Wyborn, 1982; Wyborn & Page, 1983). Consequently, the felsic volcanics of the Warramunga Group are considered to be part of a continent-wide I-type melt formed between 1900 and 2000 Ma ago during a major differentiation event in the mantle (Wyborn, in Blake & others, 1984b).

The analysed samples of felsic volcanics (62) from the different formations of the **Hatches Creek Group** plot with those of **granophyre** (33) intruding the group for all analysed elements on variation diagrams, indicating that the volcanics and granophyre bodies are probably comagmatic. Little-altered samples range from 63 to 77% silica and show well-defined trends for TiO_2, Al_2O_3, P_2O_5, Th, Zr, Y, and Nb (Fig. 72). Scattering of points, especially on plots of Fe_2O_3, MgO, CaO, Na_2O, K_2O, Rb, and Sr, is attributed to the effects of weathering, metamorphism, and metasomatism. The felsic rocks of this suite differ from those of the Warramunga Group (and the Leichhardt suite of the Mount Isa Inlier) in having higher contents of TiO_2, P_2O_5, Th, U, and especially Zr, Nb, and Y (Fig. 72), and lower amounts of Ca, Al, Sr and V. Compared with other felsic volcanics of the Mount Isa Inlier (e.g., Wyborn, in Blake & others, 1984b), those of the Hatches Creek Group have significantly lower Zr, Nb and Y contents than the A-type 1790 Ma-old Bottletree suite and 1780 Ma-old Argylla suite, and are not as potassic as the 1680 Ma-old Carters Bore suite.

The **Hill of Leaders Granite** samples plot with the felsic volcanics of the Warramunga Group for most elements, but are generally lower in CaO and higher in Li, Rb, Cr, and Ni contents. No samples of unnamed granite older than the Hatches Creek Group have been analysed.

Analysed samples of **Elkedra Granite, Devils Marbles Granite,** and **unnamed granite** (from the Murray Downs and Mia Mia Domes) are generally similar to one another in chemistry. Compared with other felsic igneous rocks of the

TABLE 3. CHEMICALLY ANALYSED IGNEOUS ROCKS (individual analyses, with sample localities, are given in accompanying microfiche).

Unit	*No. of analyses*	*Remarks*
WARRAMUNGA GROUP	9	Samples of felsic volcanics, 8 from northern KURUNDI REGION, 1 from DEVILS MARBLES REGION; 64-77% SiO_2.
HATCHES CREEK GROUP		
Epenarra Volcanics	7	Samples of felsic lava from KURUNDI REGION; 1 sample highly silicified, others have 70-75% SiO_2.
Kurinelli Sandstone	1	Mafic lava from DEVILS MARBLES REGION; 56% SiO_2.
Edmirringee Volcanics	10	1 sample of felsic lava (67% SiO_2), 9 samples of mafic lava (47-54% SiO_2), all from KURUNDI REGION.
Treasure Volcanics	27	24 samples of felsic lava—18 from HATCHES CREEK REGION and 6 from ELKEDRA REGION—with 69.5-75.5% SiO_2; 7 of these, including 4 from the Hatches Creek tungsten field, are extensively altered (e.g., have $K_2O/Na_2O>5$). 3 samples of mafic lava (44-48% SiO_2) from HATCHES CREEK REGION.
Mia Mia Volcanics	3	Highly altered felsic volcanics, 2 with $K_2O/Na_2O>20$, from HATCHES CREEK REGION.
Yeeradgi Sandstone	1	Felsic lava (65% SiO_2) from KURUNDI REGION.
Arabulja Volcanics	2	Samples of felsic lava (70% SiO_2) from HATCHES CREEK REGION and ELKEDRA REGION.
Newlands Volcanics	24	Samples of felsic volcanics (63.5-76.5% SiO_2) from HATCHES CREEK REGION and ELKEDRA REGION.
Kudinga Basalt	10	Samples of basaltic lava (49-55.5% SiO_2): 5 from HATCHES CREEK REGION, 4 from KURUNDI REGION, 1 from DEVILS MARBLES REGION.
GRANOPHYRE (sills)	33	22 samples from HATCHES CREEK REGION, 9 from ELKEDRA REGION, 2 from KURUNDI REGION: 63.0-74.5% SiO_2.
DOLERITE/GABBRO	18	17 samples from HATCHES CREEK REGION; 1 from KURUNDI REGION: 46.0-55.5% SiO_2.
DOLERITE (dykes)	1	Sample from DEVILS MARBLES REGION; 49% SiO_2.
LAMPROPHYRE (dykes)	2	Samples from KURUNDI REGION; 58.3 and 59.3% SiO_2.
UNNAMED FELDSPAR PORPHYRY	1	Sample from DEVILS MARBLES REGION; 64.6% SiO_2.
HILL OF LEADERS GRANITE	9	7 samples from KURUNDI REGION; 2 from DEVILS MARBLES REGION; 64.2-75.5% SiO_2.
ELKEDRA GRANITE	5	Samples from ELKEDRA GRANITE; 74.0-75.7% SiO_2.
DEVILS MARBLES GRANITE	2	Samples from DEVILS MARBLES REGION; 73.6 and 74.3% SiO_2.
UNNAMED GRANITE	4	2 samples from HATCHES CREEK REGION—74.0% SiO_2 (Mia Mia Dome) and 67.3% SiO_2 (NE of Hatches Creek); 1 from KURUNDI REGION—72.9% SiO_2 (Murray Downs Dome); 1 from SE of Elkedra Granite (70.9% SiO_2).

Davenport province, they have low TiO_2, Ba, Th, Zr, and Y contents, moderate to low Sr, moderate to high P_2O_5, Li, U, and Nb, and high Al_2O_3, Rb, and Sn. The Elkedra Granite and the unnamed granite in the Mia Mia Dome are especially low in Zr (as also is the unnamed granite in the Murray Downs Dome), La, and Ce. The Devils Marbles Granite is relatively high in Sr. The only analysed sample of unnamed granite from the central north of HATCHES CREEK REGION has relatively high contents of Li, Th, Rb, La, and Ce, and low TiO_2. The one analysed sample from the unnamed granite exposed southeast of the Elkedra Granite lies within the field of felsic volcanics of the Hatches Creek Group for all elements except Zr, which is relatively high.

The one analysed sample of **unnamed feldspar porphyry** intruding the Warramunga Group is similar in chemistry to the felsic volcanics of this Group, except it has lower CaO and higher Zr contents; and is anomalously rich in W (170 ppm).

Mafic rocks

Like those of felsic composition, the analysed mafic igneous rocks (44-56% SiO_2) are somewhat altered. However, as shown in Fig. 73, they have the linear trends indicative of fractionation on plots of incompatible oxides and trace elements generally regarded as being relatively immobile during alteration processes, such as TiO_2, P_2O_5, Zr and Y, against M number (after Cox, 1980). On these plots, the mafic lavas of the Hatches Creek Group and the mafic sills intruding the group are indistinguishable, except that the lavas of Kudinga Basalt are slightly richer in Zr. Low contents of TiO_2 (less than 1.5%), P_2O_5 (less than 0.25%), Zr (less than 200 ppm) and Y (less than 40 ppm) for the mafic rocks of the province are comparable to those of most Proterozoic mafic rocks of the Mount Isa Inlier, which are classified by Bultitude & Wyborn (1982) as continental tholeiites.

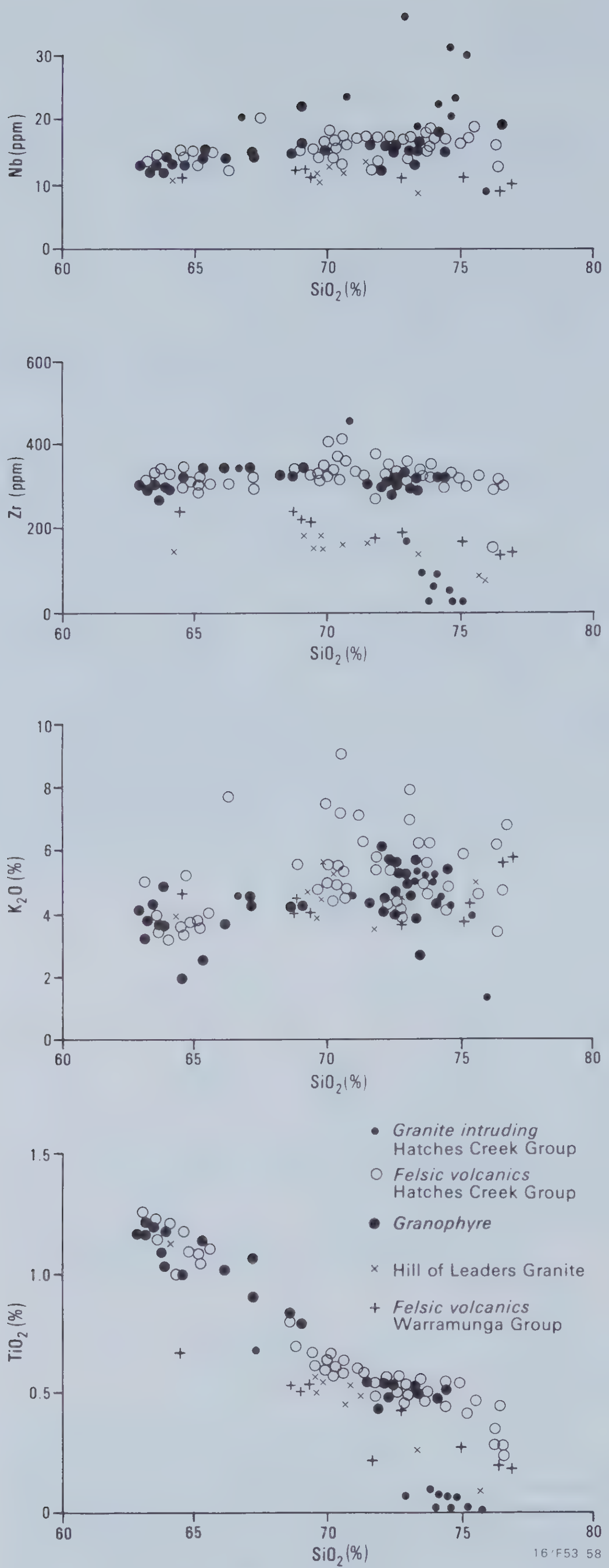


Fig. 72. Variation diagrams of selected major oxides and trace elements for felsic igneous rocks of the Davenport province.

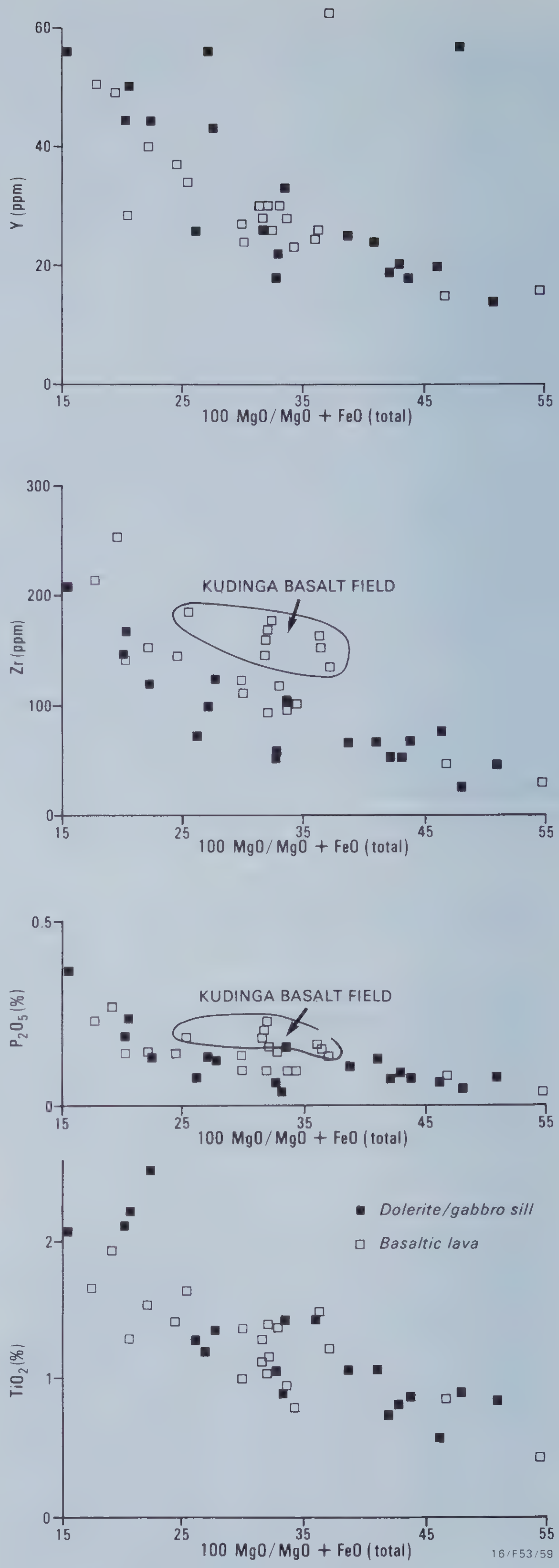


Fig. 73. Abundances of selected major oxides and trace elements plotted against M number (= 100 MgO/MgO + total Fe as FeO) for mafic igneous rocks of the Davenport province.

Lamprophyre

Two samples of lamprophyre intruding the Hill of Leaders Granite in the Mosquito Creek tungsten field, northern KURUNDI REGION, have been analysed. Both have intermediate silica (58.4, 59.4%), high K_2O (7.8, 8.3%), and low Na_2O (0.6%, 0.6%) contents, and high values for the trace elements Ba, Li, Rb, Th, U, Zr, Nb, La, Ce, Nd, Cr, Ni, Zn, Sn, W, Bi, and Be.

Trace elements of economic significance

As the igneous rocks of the Davenport province host tungsten, gold, and minor copper, silver/lead, uranium, bismuth and molybdenum mineralisation, most of the samples submitted for chemical analysis were analysed for W, and all were analysed for Cu, Pb, U, Bi, and Mo, and also for Sn, Cr, Ni, Co, and Zn. However, no Au or Ag analyses are available.

Tungsten and tin. Most felsic and mafic igneous rocks of the province have less than 5 ppm W and 8 ppm Sn. A few felsic volcanics of the Hatches Creek Group contain 5–9 ppm W, and 15 ppm W is present in one sample of Mia Mia Volcanics. Anomalously high W and Sn values are present in samples of Elkedra Granite (16–46 ppm W, 20–30 ppm Sn), Devils Marbles Granite (10–12 ppm W, 10–16 ppm Sn), and unnamed granite in the Mia Mia Dome (12 ppm W, 20 ppm Sn); each of these granites is spatially associated with tungsten mineralisation. Three samples of altered felsic lava from the Hit or Miss mine in the Hatches Creek tungsten field range from 78 ppm to 160 ppm in Sn, but have not been analysed for W. A sample of granophyre exposed 3 km to the northwest contains 15 ppm Sn and less than 3 ppm W. The single analysed sample of feldspar porphyry, collected well away from any known mineralisation, has 170 ppm W, but only 3 ppm Sn.

Copper. Few felsic rocks have more than 20 ppm Cu, although 247 ppm Cu was recorded for one felsic volcanic from the Warramunga Group in DEVILS MARBLES REGION. Most of the mafic rocks analysed have between 20 and 75 ppm Cu.

Lead. Most analysed rocks have less than 40 ppm Pb, although 80 ppm Pb is present in one sample of Kudinga Basalt and one of Newlands Volcanics.

Uranium and thorium. Between 1 ppm and 6 ppm U was found in most of the felsic and mafic rocks analysed. Much higher amounts, however, occur in the Devils Marbles Granite (25 and 30 ppm) and in two samples of Elkedra Granite (16 and 18 ppm). Thorium values for the felsic rocks lie mainly between 20 and 30 ppm, but range from 5–50 ppm. Less than 10 ppm Th is present in most mafic rocks.

Bismuth and molybdenum. Except for three samples of altered felsic lavas from the Treasure Volcanics at the Hit or Miss mine, in the Hatches Creek tungsten field, which contain 15–25 ppm Bi, no Bi has been detected in the analysed rocks. Mo contents are generally less than 5 ppm, but range up to 10 ppm.

Chromium and nickel. Most of the felsic rocks have less than 20 ppm Cr and 10 ppm Ni, whereas the mafic rocks commonly have 50–100 ppm Cr and 10–70 ppm Ni, with maximum values of 1100 ppm Cr and 300 ppm Ni. These two trace elements are particularly abundant in samples of basalt from the Treasure Volcanics.

Cobalt and zinc. The felsic and mafic rocks have up to 40 ppm and 65 ppm Co, respectively. Zn contents are very variable, but are generally less than 50 ppm in felsic rocks and between 50 ppm and 200 ppm in mafic rocks.

PHANEROZOIC COVER

(DHB)

The Proterozoic rocks of the Davenport province are overlain unconformably by flat-lying sedimentary rocks of Cambrian, Devonian?, Mesozoic?, and Cainozoic age.

Palaeozoic

Cambrian

Cambrian sedimentary rocks crop out as mesas and low hills within the Davenport province and around the northern, eastern, and southern margins. They belong to the Georgina Basin succession, and have been assigned to the Andagera Formation (in KURUNDI REGION, DEVILS MARBLES REGION, and ELKEDRA REGION), Gum Ridge Formation (in HATCHES CREEK REGION and KURUNDI REGION), and Sandover beds (in ELKEDRA REGION). However, they are grouped together as undivided Cambrian on the 1:250 000 geological map of the Davenport province.

The *Andagera Formation* is a newly defined Early Cambrian to early Middle Cambrian unit (Stidolph & others, in press) which was previously mapped as part of the Gum Ridge Formation in *Frew River* and *Bonney Well*, Sandover beds in *Elkedra*, and Tomahawk beds in *Barrow Creek*. It forms mesas and terraces partly filling many of the valleys cut into rocks of the Hatches Creek Group. These valleys, therefore, must have already been in existence when the unit was deposited. The main rock type is conglomerate (Fig. 74) made up of commonly imbricated, subrounded to subangular clasts up to 1 m across of Hatches Creek Group arenites, in a matrix of porous clayey sandstone. The formation is considered to be of fluvial origin.

The *Gum Ridge Formation* and *Sandover beds* are shallow-marine Middle Cambrian units which crop out around the margins of the province. They consist of fine-grained sandstone, siltstone, and chert which in places contain trilobites, brachiopods and hyolithids. The Sandover beds are taken to include some rocks previously mapped in *Barrow Creek* (Smith & Milligan, 1964) as Cambro-Ordovician Tomahawk beds.

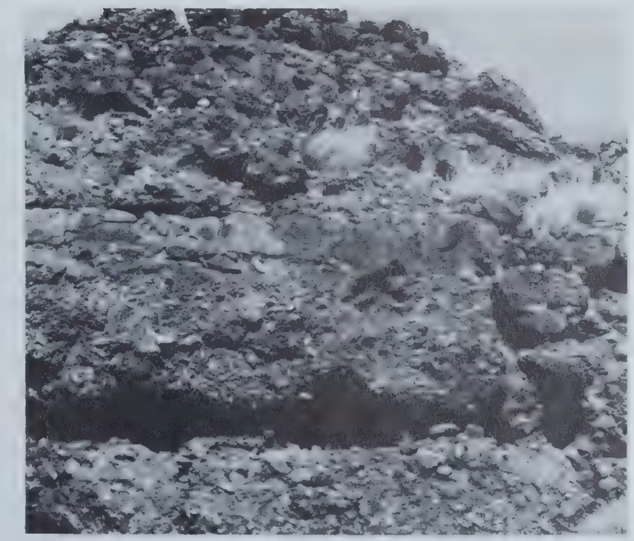


Fig. 74. Interbedded sandstone and conglomerate of the Cambrian Andagera Formation in KURUNDI REGION (at GR MS562988). Thickness shown is 3 m. (M2541/17A)

As discussed by Stewart & others (1986), the marine Cambrian rocks conformably overlie and probably interfinger with the fluvial Andagera Formation; the central part of the Davenport province was a land area during the Cambrian and has probably remained so throughout the Phanerozoic;

the tops of mesas formed of Andagera Formation are lower than the flat tops of adjacent ridges formed of Hatches Creek Group arenites (Fig. 75), and are thought to be remnants of river terraces that have existed as subaerial landforms since the early Middle Cambrian; and the higher flat tops of adjacent ridges are remnants of a peneplain, the Ashburton Surface, which was dissected before the Andagera Formation was deposited and is therefore Early Cambrian or older.

Devonian?

Unfossiliferous sandstone of possibly Devonian age forms low flat-topped hills on plains to the southwest and northwest of the Davenport province. The sandstone has been tentatively assigned to the Dulcie Sandstone of the Georgina Basin in ELKEDRA REGION and the Lake Surprise Sandstone of the Wiso Basin in DEVILS MARBLES REGION.

Mesozoic?

Bleached sandstone, conglomerate and minor mudstone forming low hills and mesas, with level to gently sloping tops within the Davenport province (Fig. 76), have been mapped as possibly Mesozoic. They are probably fluvial deposits. The sandstone is generally poorly sorted, poorly bedded, and, like the Devonian? sandstone, commonly has pitted weathered surfaces. Lithologically, the unit more closely resembles fluvial sedimentary rocks of the Mesozoic Gilbert River Formation exposed in the Mount Isa region to the east (e.g., Blake & others, 1984b) than the Cambrian Andagera Formation; however, some outcrops of Mesozoic? could be Cambrian.

The tops of the mesas mapped as Mesozoic? are typically much lower than nearby ridges of Hatches Creek Group rocks, and appear to be remnants of fluvial terraces and gently sloping alluvial fans that originally flanked these ridges.

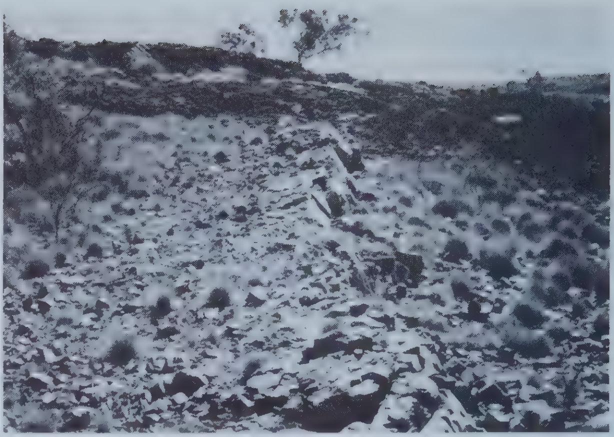


Fig. 76. Mesozoic? conglomerate unconformably overlying gentle dippling (to west) arenite of the Unimbra Sandstone, Hatches Creek Group, on the east side of the Murchison Range, DEVILS MARBLES REGION (at GR MT337805). (M2567/29)

Cainozoic

Valley floors within the Davenport province and plains around the margins are covered by Cainozoic surficial sediments. Three units are distinguished on the 1:250 000 geological map: *Qa*, which consists of Quaternary silt, sand, clay, and gravel deposited on presently active flood plains; *Czk*, which represents calcrete, a cellular inorganic limestone probably formed by evaporation of groundwater during the Cainozoic; and *Cz*, which comprises undivided colluvial, aeolian, alluvial, and residual sand, silt, clay and gravel, together with minor patches of ferricrete and silcrete. Unit Cz includes unconsolidated sediments deposited on active alluvial fans and also poorly consolidated gravels forming dissected alluvial fans that may be mainly Tertiary.

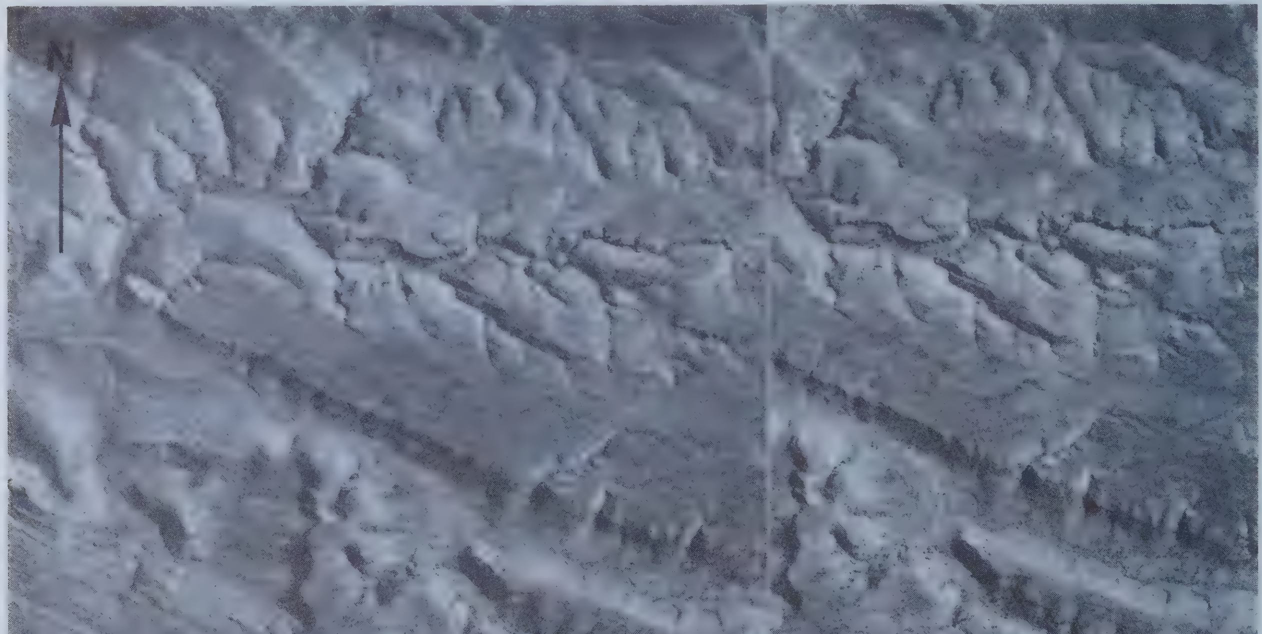


Fig. 75. Stereoscopic pair of vertical aerial photographs showing dissected Cambrian river terraces in valleys cut into the Proterozoic Hatches Creek Group in KURUNDI REGION (centre of view at GR MT579023). The flat tops of the ridges between the valleys are part of the Ashburton Surface, which is Cambrian or older. (Davenport Range, run 8, photos 1155 and 1156, CAB/C15, 20.9.1980)

GEOPHYSICAL INVESTIGATIONS

(IGH)

The Davenport province and surrounding areas have been covered by BMR regional gravity surveys (station spacing about 11 km) and BMR and NTGS airborne magnetic and gamma-ray spectrometric surveys. Most of the airborne surveys were carried out by BMR using flight lines 3-3.2 km apart, but the Hatches 1:100 000 Sheet (by BMR) and *Barrow Creek* (by NTGS) were flown in more detail in 1981, with flight lines 400-500 m apart and 100 m above ground level. Relatively detailed magnetic surveys of local areas have been made by mineral exploration companies. In 1982 BMR carried out some detailed gravity and carborne magnetometer and gamma-ray spectrometer traverses to supplement the regional data. Details of the surveys and availability of the data are given in the map commentaries for HATCHES CREEK REGION (Blake & others, 1986a), KURUNDI REGION (Stewart & Blake, 1986), DEVILS MARBLES REGION (Wyche & others, 1987), and ELKEDRA REGION (Blake & Horsfall, 1987). Physical properties (density, magnetic susceptibility, remanence, and Koenigsberger ratios) of representative rocks exposed in the Davenport province have been determined by Hone & others (in preparation). Geophysical characteristics of the Davenport province were described and discussed in a paper delivered at the 12th BMR Symposium (Hone, 1983).

Rock density

Density measurements of Proterozoic rocks exposed in the Davenport province are summarised in Table 4. Mafic rocks are the most dense and arenites the least dense. In the Hatches Creek Group, the highest proportion of mafic rocks occurs in the Ooradidgee Subgroup, which has a significantly higher overall density, and gives rise to higher gravity values, than the Hanlon Subgroup. The Wauchope Subgroup has an intermediate overall density. Granites intruding the Hatches Creek Group appear to have lower densities than the older granites in the northwest.

TABLE 4. SUMMARY OF DENSITY MEASUREMENTS (from Hone & others, in prep.).

		Density (t/m^3)	
Unit	*N*	*Range*	*Mean*
Mafic sills	22	2.80-3.12	2.98
Granophyre sills	6	2.65-2.70	2.69
Mafic volcanics	59	2.77-3.33	2.94
Felsic volcanics	35	2.59-2.88	2.72
Sandstones	32	2.36-2.89	2.64
Granites intruding Hatches Creek Group	5	2.63-2.68	2.65
Granites predating Hatches Creek Group	9	2.68-2.74	2.71

Regional gravity

The regional gravity field over the Davenport province and surrounding area is shown in Fig. 77. Gravity values range

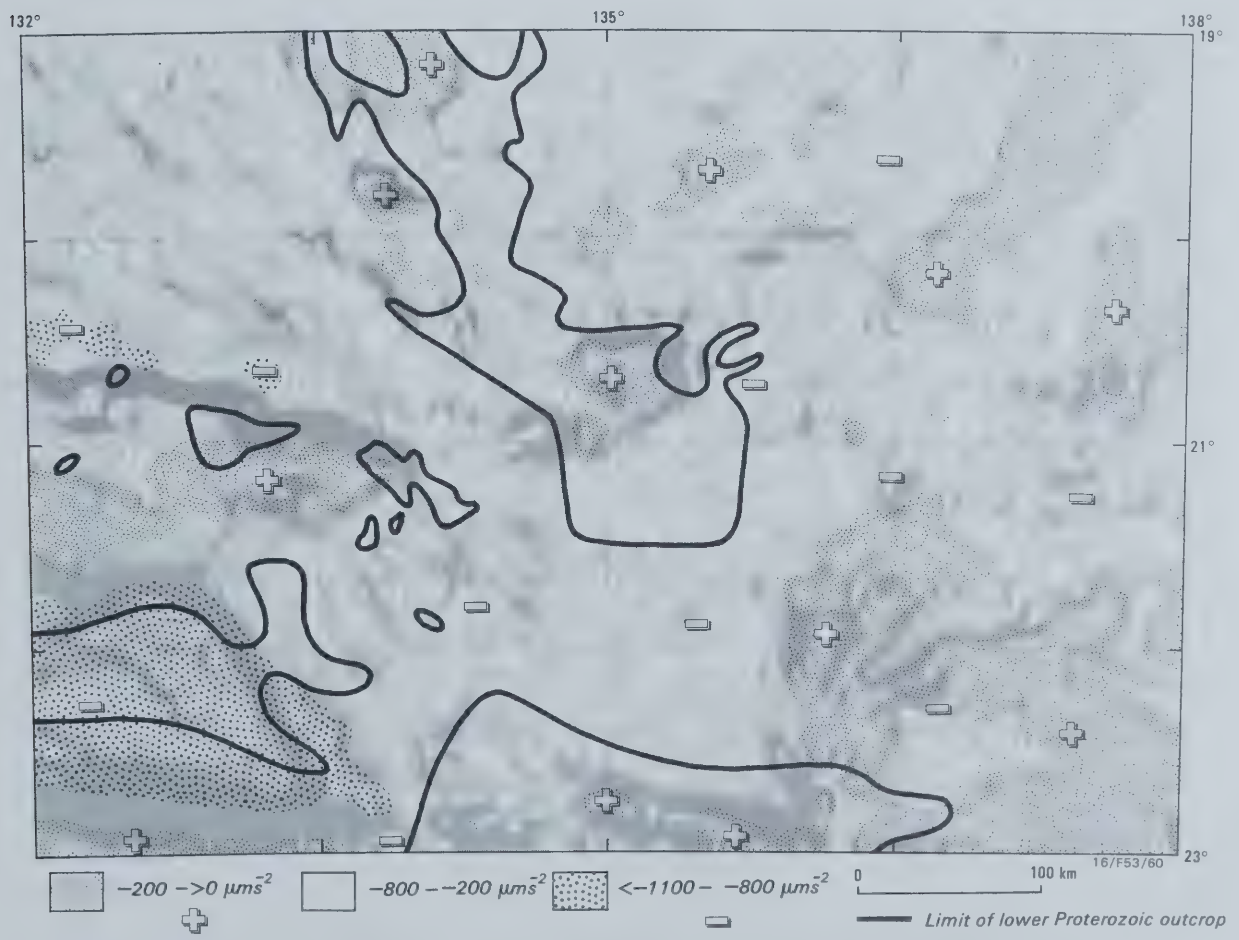

132°
135°
138°
19°
21°
23°
16/F53/60
−200 −>0 μms^{-2}
−800 − −200 μms^{-2}
<−1100− −800 μms^{-2}
0
100 km
Limit of lower Proterozoic outcrop

Fig. 77. Bouguer anomaly contour map of the Davenport province and surrounding area. Contour interval 20 μms^{-2}.

from less than -1100 m/s^2 to over 200 m/s^2, with the more extreme values being located outside the Davenport province—strong lows in the west over the Wiso Basin and in the southwest over the Ngalia Basin, and highs over rocks of the Arunta Inlier to the southwest and south.

In Fig. 78, which shows gravity contours over *Frew River, Elkedra, Barrow Creek,* and *Bonney Well,* the gravity highs and lows correlate in general with the broad distribution of the Ooradidgee Subgroup and the Wauchope and Hanlon Subgroups, respectively. The Devils Marbles Granite, unnamed granite in northeastern HATCHES CREEK REGION, and unnamed granite in the Mia Mia Dome, all of which intrude the Hatches Creek Group, have strong gravity lows over them. These intrusions are interpreted as steep-sided plutons extending to depths of about 15 km (Figs 78 & 79). In contrast, granites intruding the Warramunga Group in the north of the province, and probably predating the Hatches Creek Group, have less marked gravity anomalies, and are interpreted as having a smaller depth extent (e.g., Fig. 79, traverse 28).

Magnetic properties

Laboratory measurement of magnetic susceptibilities of representative samples from the Davenport province are summarised in Table 5. Arenites from the Hatches Creek Group are virtually nonmagnetic. Granites, not shown in the Table 5, have low uniform magnetic susceptibilities. The most magnetic samples measured come from the Edmirringee Volcanics. Basalt samples from the Kudinga Basalt have a lower magnetic susceptibility than those of other units. Four drill core samples of felsic volcanics probably from the Warramunga Group have high magnetic susceptibilities.

A strong remanent magnetic component is present in most of the magnetic samples. Although the remanent direction is fairly close in places to the earth's field, it is commonly sufficiently different to cause significant errors in estimates of dip.

Regional magnetic characteristics

Magnetic marker horizons evident from airborne and ground surveys occur in volcanic units and sills within the Hatches Creek Group. The strongest anomalies arise from sources in the Edmirringee Volcanics and mafic sills within the Ooradidgee Subgroup. The only magnetic marker in the Hanlon Subgroup is mafic lava within the Alinjabon Sandstone. Some sources in felsic volcanic units, especially in the Treasure Volcanics and Mia Mia Volcanics, give moderate strength magnetic anomalies.

Aeromagnetic contours over the Davenport province and surrounding area are shown in Fig. 80, which is a compilation of the results from a number of surveys in which different survey and presentation parameters were used. The aeromagnetic contour maps, especially those resulting from the recent more detailed surveys, show that the Hatches Creek Group can commonly be readily distinguished beneath cover rocks. This is because magnetic units within the group (mafic

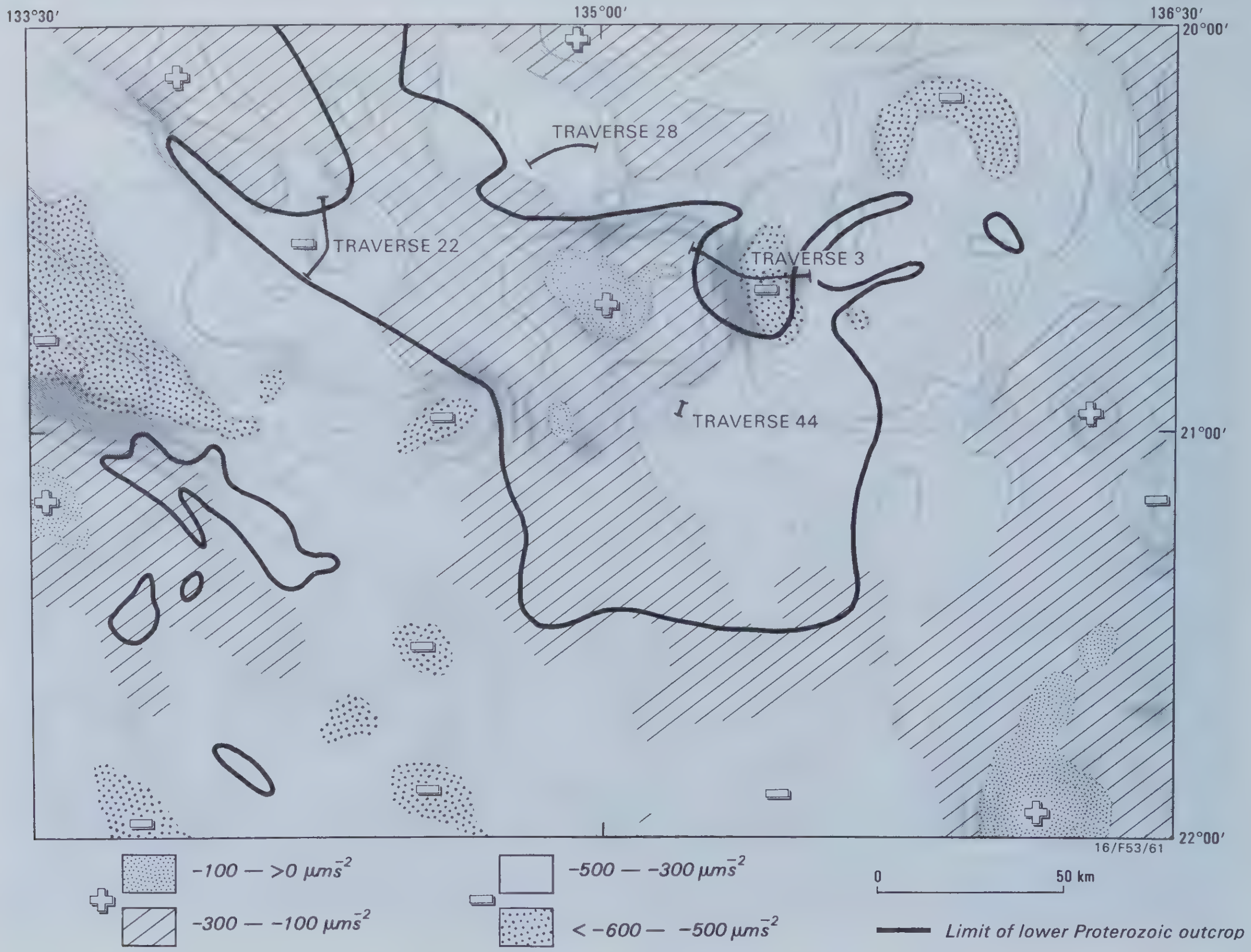


Fig. 78. Bouguer anomaly contour map of the Davenport province (*Bonney Well, Frew River, Barrow Creek,* and *Elkedra*). Contour interval 20 μms^{-2}.

TABLE 5. SUMMARY OF MAGNETIC SUSCEPTIBILITIES, REMANENCES, AND KOENIGSBERGER RATIOS.

Unit	*Rock type*	*Number of samples*	*Susceptibility (μSI)*			*Remanence (mA.m⁻¹)*			*Koenigsberger ratio*		
			Range	*Median*	*Mean*	*Range*	*Median*	*Mean*	*Range*	*Median*	*Mean*
—	laterite	2	810–1000	910	910	2–100	51	51	0.05–2.96	1.50	1.50
Felsic intrusives	granophyre	6	2570–23 510	8160	11 120	70–6500	1850	2378	0.66–21.37	2.96	6.00
	granite intruding Hatches Creek Group	5	120–1180	220	400	0.2–150	2	34	0.03 3.04	0.19	0.95
	granite intruding Warramunga Group	7	150–850	330	380	1–85	20	26	0.08–4.95	1.44	1.71
Mafic intrusives	dolerite, gabbro	23	490–84 160	2510	13 490	0.14–300 000	850	20 506	0.02–262	7.21	35.11
Canulgerra Sandstone	quartz arenite	1	—	0	0	—	5	5	—	—	—
Alinjabon Sandstone	quartz arenite	3	150–200	200	180	0.6–12	0.8	4	0.01 1.15	0.10	0.45
	basalt	11	300–49 420	2810	12 130	2–10 000	125	1710	0.09–7.69	2.36	3.10
Errolola Sandstone	quartz arenite	4	0–1300	70	370	1–7	3	4	0.1–1.92	1.22	1.08
Kudinga Basalt	basalt	30	140–29 100	810	2390	0.5–2400	3	188	0.01–25.64	0.10	1.26
Coulters Sandstone	quartz arenite	6	0–40	0	10	0.5–70	10	18	—	45	45
Arabulja Volcanics	felsic volcanics	3	10–6000	2600	2870	60–150	100	103	0.24–283.02	0.92	94.73
Newlands Volcanics	felsic volcanics	12	400–47 490	5340	9940	20–4500	175	994	0.18–10.43	1.72	3.04
Yeeradgi Sandstone	arenite	2	10–840	740	740	—	6	6	1.05–11.0	6.03	6.03
	siltstone, claystone	7	220–840	380	470	0.8–45	9	19	0.07–4.52	0.56	1.09
Unimbra Sandstone	arenite	4	30–330	140	160	1–550	1	138	0.06–55.0	1.22	14.13
Mia Mia Volcanics	felsic volcanics	3	50–240	80	120	1–4	3	3	0.10–1.50	0.96	0.85
	quartz arenite	1	—	240	240	—	550	550	—	55.0	55.0
Treasure Volcanics	felsic volcanics	19	10–22 000	380	2440	1–57 500	50	3201	0.07–578	—	—
	basalt	8	390–8230	1330	2690	1–2200	65	596	0.03–19.41	0.82	4.35
Taragan Sandstone	arenite	6	0–90	20	30	0–15	2	4	0.08–1.92	1.28	1.09
Kurinelli Sandstone	arenite	5	0–1030	400	490	0–520	35	161	0.02–50	4.05	14.53
Rooneys Formation	siltstone	1	—	200	200	—	1	1	—	0.12	0.12
Epenarra Volcanics	felsic volcanics	9	140–4750	360	940	0.8–1200	30	227	0.11–27	1.90	5.24
	siltstone, arenite	5	170–370	300	280	0.5–350	15	80	0.03–48	2.00	10.92
Edmiringee Volcanics	mafic volcanics	14	6580–129 730	69 120	67 540	400–65 000	3500	9604	0.02–44.38	1.09	6.23
Warramunga Group	sedimentary rocks, porphyry	14	20–149 110	15 400	24 820	0.3–11 200	400	1797	0.03–9.22	0.69	1.48

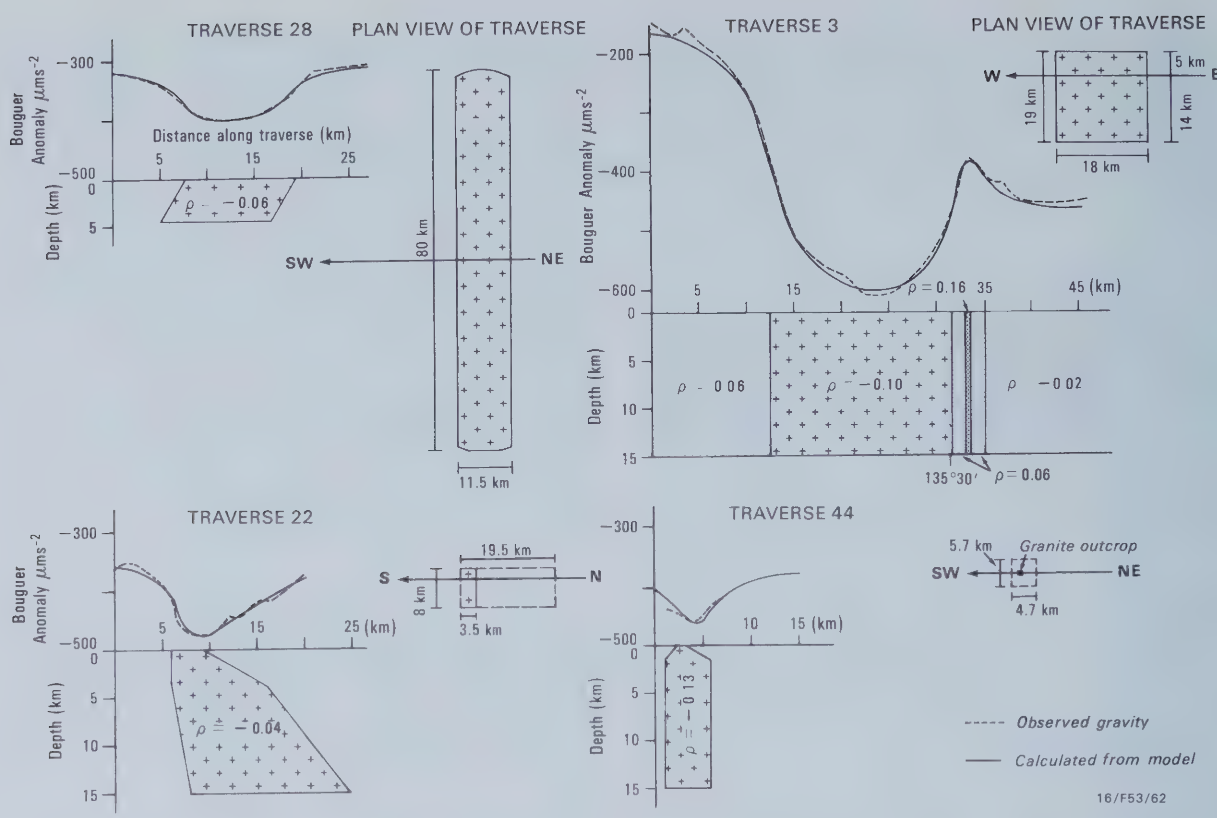


Fig. 79. Gravity anomalies over granites of the Davenport province, and model sections. See Fig. 78 for locations of traverses.

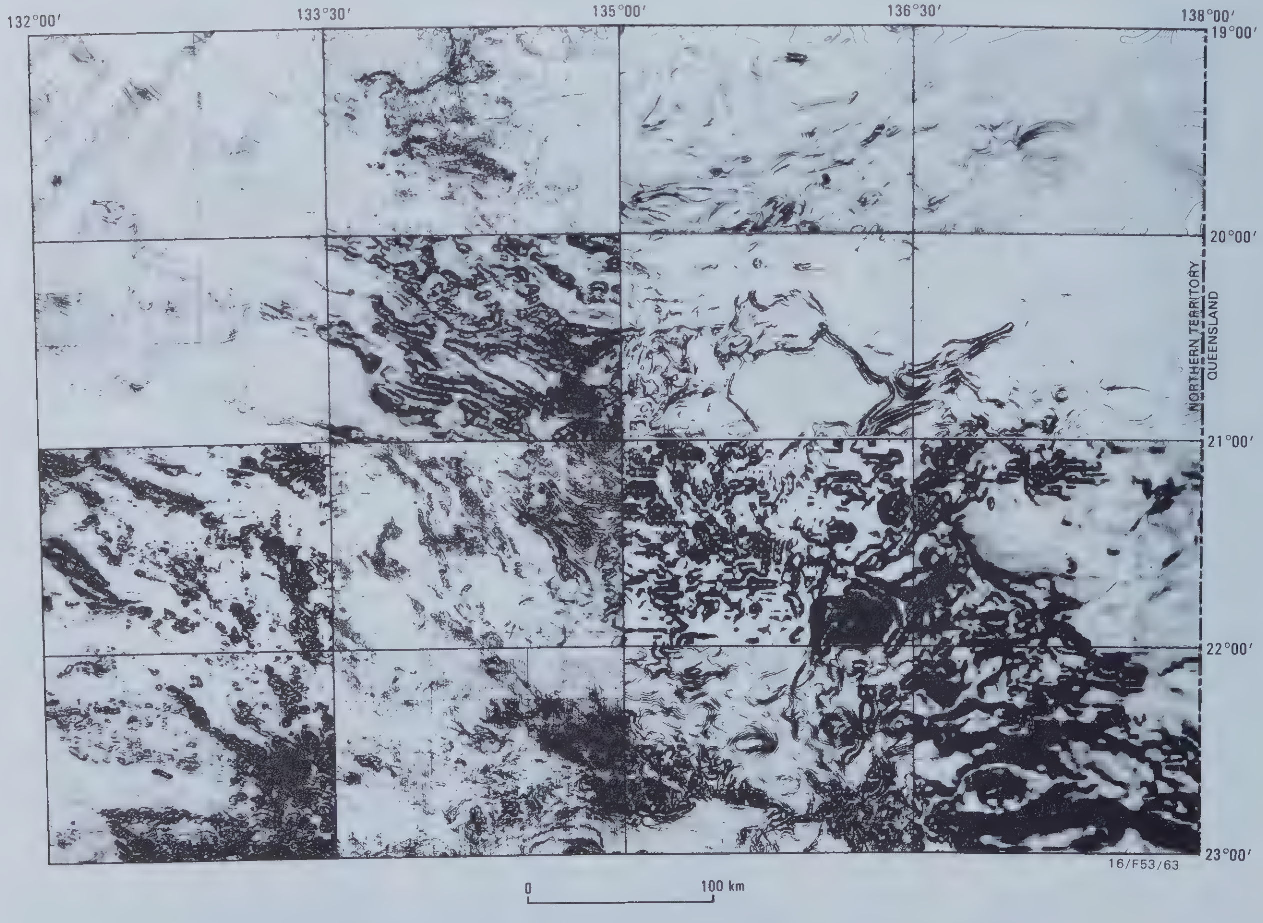


Fig. 80. Aeromagnetic contour map of the Davenport province and surrounding area.

volcanics, some felsic volcanics, and mafic sills) alternate with non-magnetic units (arenites and other sedimentary rocks), giving rise to characteristic curvilinear anomalies which are parallel to strike of bedding and outline major structures (e.g, Tucker & others, 1979; Hone, 1983; Blake & others, 1986). Rocks of the Warramunga Group range from moderately magnetic to non-magnetic. No ironstones of the type found in the Warramunga Group near Tennant Creek have been detected. The granite bodies in the Davenport province have low and quiet magnetic fields over them, and do not have magnetic contact aureoles.

The aeromagnetic contours can be used to estimate the lateral extent of the Hatches Creek Group in the subsurface. An interpretation of Fig. 80 is given in Fig. 81; this shows the Hatches Creek Group extending for a considerable distance beyond its exposed limits and being linked in the subsurface with the Tomkinson Creek beds to the northwest. The Tomkinson Creek beds, which crop out north of Tennant Creek, have a similar magnetic expression to the Hatches Creek Group. In an interpretation of the regional geophysical data for the Georgina Basin, Tucker & others (1979) suggested that the Hatches Creek Group could be traced from the Davenport province eastwards for at least 300 km beneath a cover of Georgina Basin sedimentary rocks generally less than 500 m thick. In the Wiso Basin on the west side of the Davenport province, deep troughs appear to be developed, as shown in Fig. 82, and Wilkes (in Kennewell & Huleatt, 1980) was unable to trace the Hatches Creek Group for any great distance westwards (less than 80 km). In contrast, the Tomkinson Creek beds to the north extend as a basement ridge into the central part of the Wiso Basin.

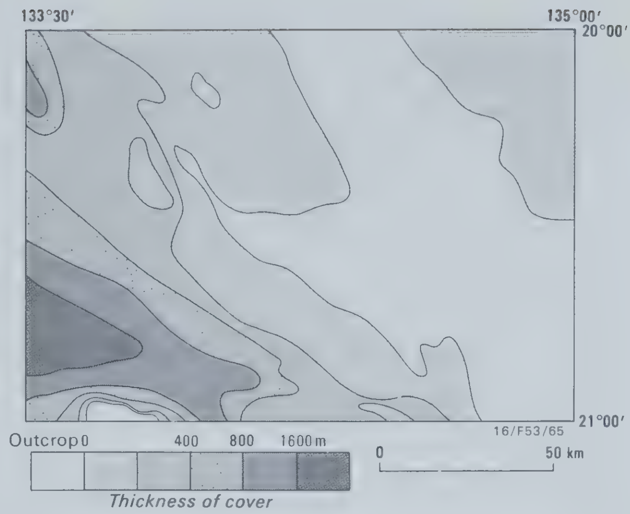


Fig. 82. Estimated thickness of cover rocks in *Bonney Well.*

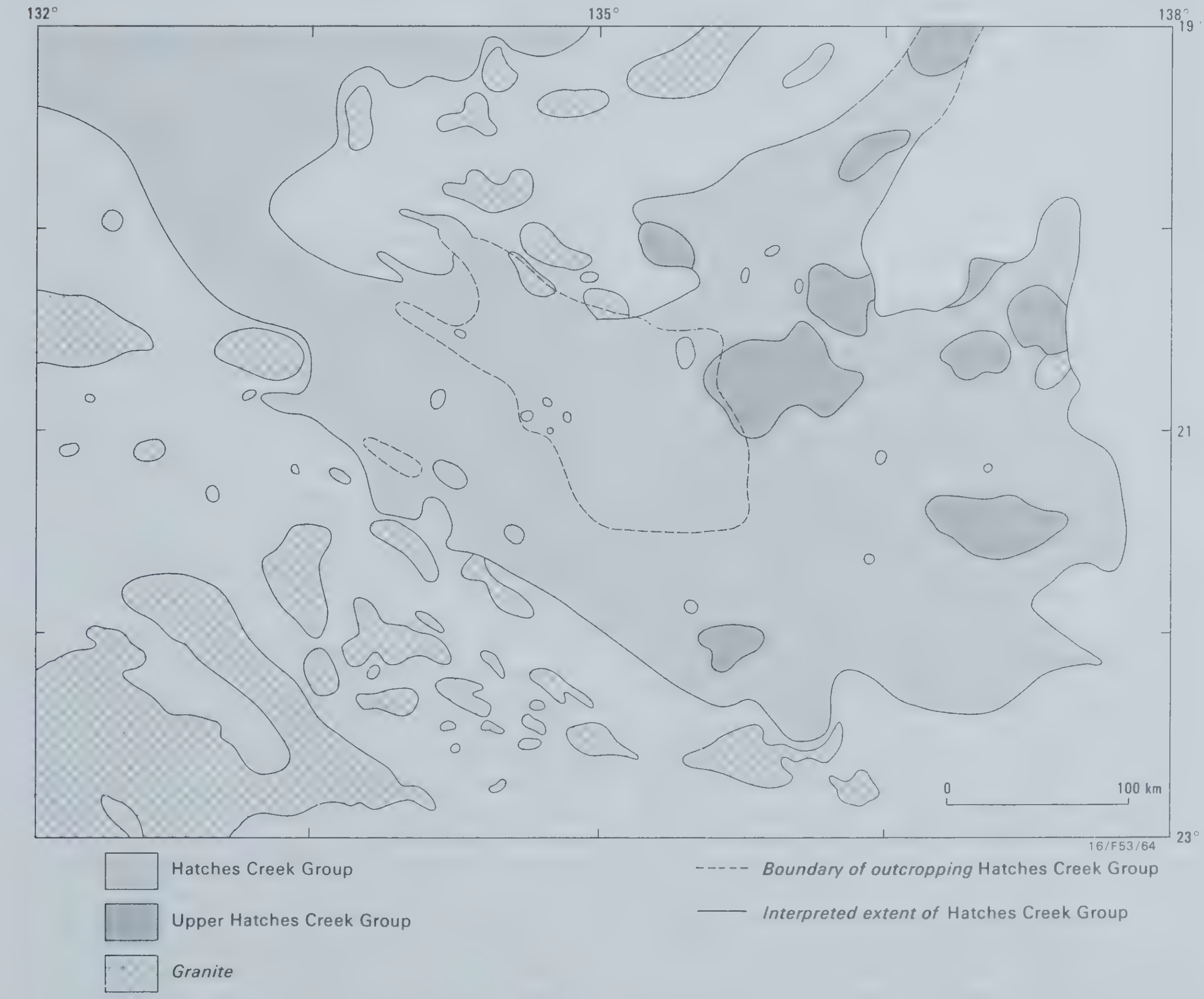

132°
135°
138°
19
21
23°
0
100 km
16/F53/64
Hatches Creek Group
Upper Hatches Creek Group
Granite
Boundary of outcropping Hatches Creek Group
Interpreted extent of Hatches Creek Group

Fig. 81. Interpretation of solid geology of the Davenport province and surrounding area from the aeromagnetic data.

Gamma-ray spectrometrics

Only the part of the Davenport province covered by *Bonney Well* (Fig. 83), *Barrow Creek*, and southwest *Frew River* (Hatches 1:100 000 Sheet) has been flown with gamma-ray spectrometrics. The data obtained indicate that exposed felsic volcanics and granites are significantly radioactive, and some volcaniclastic arenites are moderately radioactive. Other rocks are not significantly radioactive. In *Bonney Well*, the most radioactive rock unit is the Devils Marbles Granite; the Munadgee uranium prospect shows up on the airborne gamma-ray spectrometric results as a distinct high.

Estimates of crustal thickness

Tucker & others (1979) have suggested, from regional gravity and magnetic data, that the base of the crust beneath the Davenport province lies at a depth of 35-37 km. A somewhat greater depth, about 50 km, may be inferred from a seismic crustal investigation carried out along a line between Tennant Creek and Mount Isa (Finlayson, 1982).

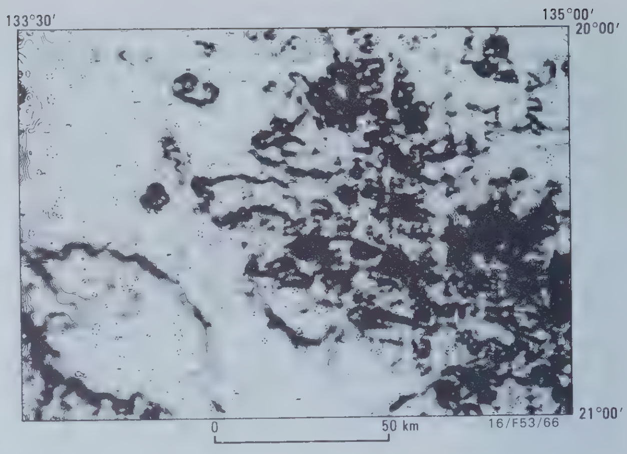


Fig. 83. Gamma-ray spectrometric total-count contours for *Bonney Well*.

MINERAL RESOURCES AND METALLOGENESIS

(DHB)

Tungsten, gold, and small amounts of copper, bismuth, lead, silver, and uranium have been extracted from the Davenport province. However, no large or medium-size mineral deposits are known, and no mines are being worked at present (1985). Available information on mines, prospects, and economic mineral occurrences is given on the 1:100 000 geological maps and in accompanying map commentaries and reports. Most of the mineral deposits occur within the Hatches Creek Group, but there are also some in the Warramunga Group, in granite, and in dolerite/gabbro intrusions (Fig. 84).

Tungsten

Most of the tungsten produced in the Davenport province has come from the Hatches Creek tungsten field in HATCHES CREEK REGION and the Wauchope tungsten field in DEVILS MARBLES REGION. Minor amounts have been obtained from the Mosquito Creek tungsten field in KURUNDI REGION, and from small mines elsewhere, such as the Juggler mine in the south of ELKEDRA REGION and the Woodenjerrie mine in northern HATCHES CREEK REGION. Total production for the province is about 4500 tonnes tungsten concentrate (about 65% WO_3).

Hatches Creek tungsten field

Mining began in the Hatches Creek tungsten field in 1913 and was carried out sporadically until late 1957, and again on a small scale in the late 1960s and early 1970s. Few of the mines (Figs 85A–C) were worked to depths greater than 30 m and none are deeper than 100 m. Most workings are now inaccessible. Details of individual mines are given by Ryan (1961) and are summarised in Blake & others (1986a). Up to 1958, about 3000 tonnes of tungsten concentrates (about 65% WO_3), 5.7 t bismuth concentrates, and 70 t copper concentrates had been produced from the field (Ryan, 1961).

The ore minerals occur in quartz veins of various orientations cutting sedimentary and felsic volcanic rocks of the Kurinelli Sandstone, Taragan Sandstone, and Treasure Volcanics of the Ooradidgee Subgroup, Hatches Creek Group, and also dolerite/gabbro intrusions. They include the tungsten minerals wolframite, scheelite, tungstite, and probably cupro-tungstite; the bismuth minerals bismutite, bismuthinite, and native bismuth; the copper minerals chalcopyrite, chalcocite, covellite, bornite, malachite, azurite, and chrysocolla; molybdenite; very sparse cassiterite; and traces of gold (Ryan, 1961). Gangue minerals, in addition to quartz, include muscovite and biotite, and probably also topaz (Hoatson & Cruikshank, 1985). The mineralised veins appear to postdate folding of the Hatches Creek Group.

The epigenetic quartz vein mineralisation is considered to be related to a concealed granite. The existence of a mineralising granite underlying the tungsten field is supported by (1) felsic lavas within the mineral field are altered to hornfels consisting of biotite, chlorite, quartz, muscovite, and porphyroblastic tourmaline; (2) the mineral field coincides with regional gravity and magnetic lows (Hoatson & Cruikshank, 1985; Blake & others, 1986a); and (3) the presence of a small outcrop of unnamed granite with anomalous W (12 ppm) and Sn (20 ppm) contents 5 km to the south of the southernmost mine in the mineral field—this granite, which intrudes the Mia Mia Volcanics in the Mia Mia Dome, may be connected at depth with the postulated concealed granite.

Emplacement of the mineralising granite may have been associated with a 1645 ± 44 Ma region-wide hydrothermal alteration event tentatively interpreted from Rb–Sr whole-rock data by Blake & Page (in press).

Wauchope tungsten field

The Wauchope tungsten field, located 12 km northeast of Wauchope Hotel on the Stuart Highway, in DEVILS MARBLES REGION, has been described by Sullivan (1952, 1953b). The tungsten deposits were found and first worked in 1917, and were mined intermittently until 1962. Subsequent bulldozing has resulted in the old mine workings, few of which were deeper than 10 m, being filled-in. Total recorded production (Smith, 1970) is about 1430 t tungsten concentrates (greater than 60% WO_3). The lodes consist of quartz veins generally less than 50 cm thick which are mainly parallel to bedding in the enclosing country rocks—a band of gently dipping siltstone and mudstone lying between quartz arenite and conglomerate of the Taragan Sandstone, Hatches

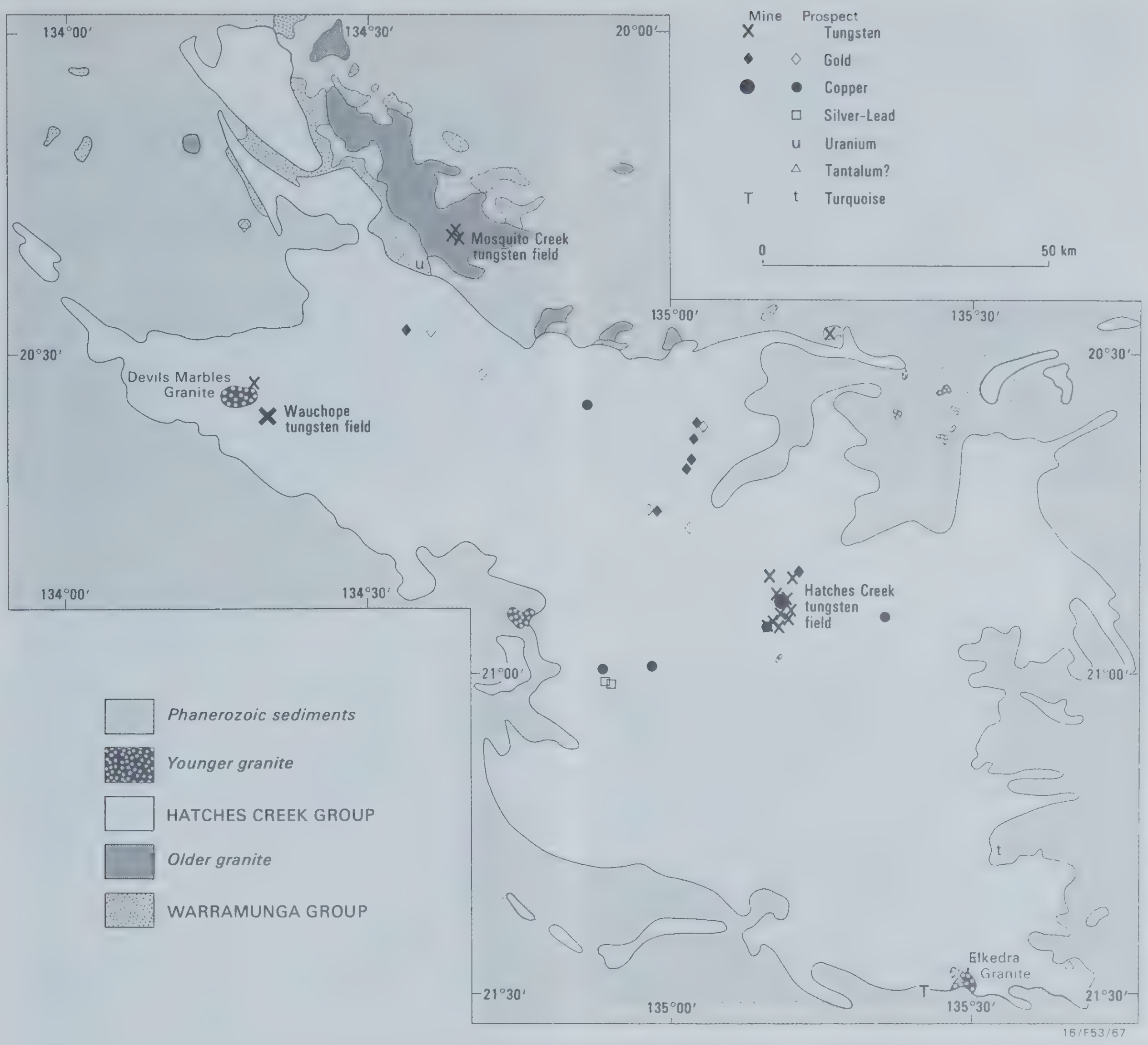


Fig. 84. Distribution of mineral deposits in the Davenport province.

Creek Group. The siltstone and mudstone have been metamorphosed to hornfels consisting of sericite + quartz + tourmaline + biotite + topaz (Dallwitz, in Sullivan, 1952).

The ore is made up of wolframite, minor scheelite, and also pyrite, chalcopyrite, molybdenite, and bismuthinite, in a gangue of quartz, muscovite, sericite, topaz, fluorite, and iron oxide. Kaolinitic wall-rock alteration is widespread.

The tungsten mineralisation is thought to be related to the Devils Marbles Granite exposed less than 5 km to the northwest. This granite, which postdates folding of the Hatches Creek Group, is cut by a wolframite-bearing quartz vein (at GR MT256258) and is probably responsible for a greisen deposit in Yeeradgi Sandstone to the northeast (at GR MT270284) that has a reported production of 250–500 kg tungsten (Sullivan, 1952).

Mosquito Creek tungsten field

The Mosquito Creek tungsten field is located 20 km north of Kurundi homestead, KURUNDI REGION. It was discovered in 1951, and before being abandoned by 1956 was visited by Joklich & Tomich (1951) and Bell (1953). The lodes are quartz veins, some with thin greisen margins, cutting Hill of Leaders Granite. The veins are up to 30 cm wide and 30 m long, and have various orientations. The main ore mineral is scheelite, which occurs together with minor wolframite in a gangue of quartz and subordinate muscovite and tourmaline. Most workings appear to have been shallow costeans (Fig. 85D), but a shaft was sunk to a depth of 28 m in 1952. The only production figures available for the field are 150 t ore treated for a return of 2.49 t tungstic oxide (WO_3) between February 1951 and August 1952 (Wyche, in press).

The mineralisation may be genetically related to lamprophyre dykes cutting the Hill of Leaders Granite: analysed samples of the granite contain 3–5 ppm W, except for two samples, both with 12 ppm W, from alongside mineralised veins, whereas lamprophyre near one of the mines contains 58 ppm W.

Juggler tungsten mine

The mineralisation at the Juggler mine (production unknown) in southern ELKEDRA REGION consists of wolframite in a quartz–tourmaline vein bordered by greisen within the Elkedra Granite. It is presumed to be related to this granite.

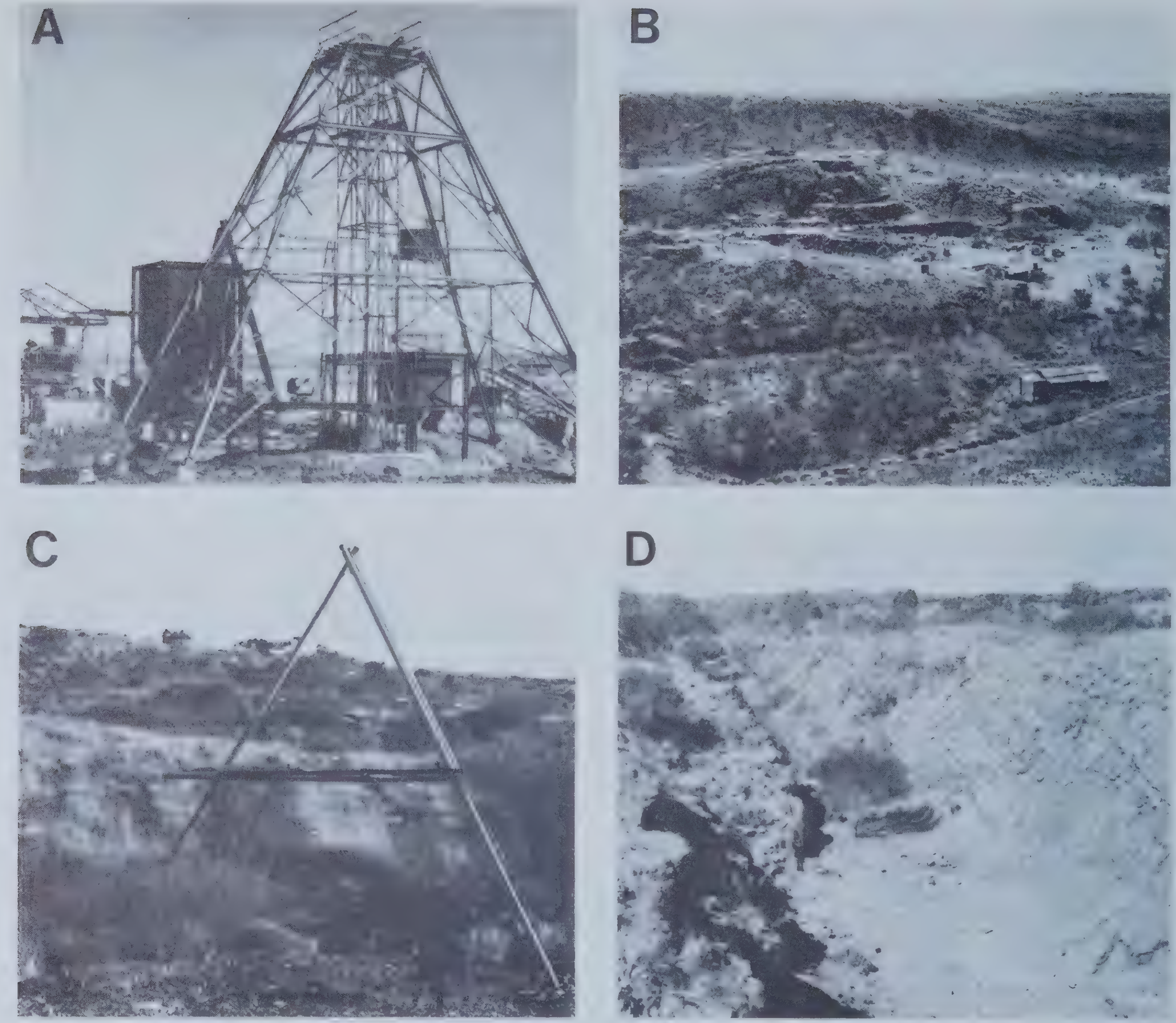


Fig. 85. Tungsten mines: (A) Head frame at the Pioneer mine, 1981 (HATCHES CREEK REGION, GR NS185920; M2695/12A). (B) Treasure mine, 1981 (HATCHES CREEK REGION, GR NS197868; M2472/23A). (C) Shaft at the Hit or Miss mine, 1983 (HATCHES CREEK REGION, GR NS195855; M2660/15). (D) Open cut at the Hill of Leaders mine, 1983 (KURUNDI REGION, GR MT822535; M2625/A).

Woodenjerrie tungsten mine

At this small mine, located 3 km southeast of Epenarra homestead in northern HATCHES CREEK REGION, wolframite occurs with pyrite and hematite in quartz veins cutting greywacke and siltstone of the Warramunga Group. Although the mineralisation resembles that typically related to granitic intrusions, no granite is exposed in the general vicinity. The mine was worked in 1952 and 1953, but no production figures are available.

Gold deposits

Gold was discovered in the Davenport province in 1898 by the Central Australian Exploration Syndicate (Davidson, 1905), but although numerous occurrences are now known in the northern part of the province, the total recorded production for the region is only about 15 kg (Roarty, 1977). Except at one locality in DEVILS MARBLES REGION (at GR MT267559), where gold is present in a shear zone within the Warramunga Group, the gold deposits are confined to the lower part of the Ooradidgee Subgroup of the Hatches Creek Group. The main deposits are at the Power of Wealth mine and the Great Davenport mine (Fig. 86A) in KURUNDI REGION, and the Crystal mine (Fig. 86B) and several small mines near the abandoned Kurinelli battery (Fig. 86C) and outstation in HATCHES CREEK REGION.

At the Power of Wealth mine, where 312 g Au was produced from about 40 t ore in 1950, and at the Great Davenport mine, which was discovered in 1964 and produced about 4.25 kg Au before being abandoned in 1965, gold-bearing quartz veins cut arenite and shale of the Kurinelli Sandstone. Similar veins at the Crystal mine and near Kurinelli cut dolerite/gabbro intrusions as well as siltstone and arenite of the Endurance Sandstone Member, Kurinelli Sandstone (Crystal mine) and Rooneys Formation (Kurinelli area).

Most if not all the gold mineralisation could be related to the main folding and regional metamorphic event affecting the Hatches Creek Group: metamorphic fluids may have scavenged gold from the lower part of the Hatches Creek Group and possibly also from mafic intrusions and deposited it in structurally and chemically favourable sites.

Copper and silver/lead deposits

The only recorded copper production has come from the Hatches Creek tungsten field (70 t), where copper minerals occur in tungsten-bearing quartz veins cutting rocks of the Ooradidgee Subgroup, Hatches Creek Group. The copper mineralisation here, like that of tungsten, may be related to a concealed granite, although some may have been derived from mafic intrusions.

Secondary copper minerals and also lead minerals have been found filling amygdale and lining joints at several localities in basaltic lavas of the Edmirringee Volcanics, Treasure Volcanics, and Kudinga Basalt of the Hatches Creek Group. They also occur with quartz in veins cutting basalt and dolerite. At the Silver Valley prospects in the Murray Downs Dome, northwestern ELKEDRA REGION, galena-bearing quartz veins cut basalt of the Edmirringee Volcanics. At all these occurrences, the copper and lead were presumably derived from the enclosing mafic rocks during deuteric or metamorphic alteration processes. Primary sulphides, especially chalcopyrite, are commonly present as accessory minerals in dolerite and gabbro intrusions.

Uranium

A uranium prospect, Munadgee, was discovered in 1955 in northern KURUNDI REGION (at GR MT563490). Here torbenite, autunite, and possibly carnotite (Lord, 1955 and 1956) occur in strongly sheared and altered feldspar porphyry which is inferred to intrude the Warramunga Group. Workings consist of two shafts (maximum depth 40 m) and several drives, cross-cuts, and costeans. Some ore has been stockpiled, but none sold. The best grade of ore recorded is 0.82% U_3O_8 over 1.2 m at a depth of 40 m.

Several radiometric anomalies have been detected within the Davenport province by airborne surveys (Livingstone, 1957; Langron, 1957), but none have proved to be of economic significance (Mulder, 1960).

Turquoise

Turquoise has been obtained from the Tosca mine in the far south of the province (at GR NS440230, ELKEDRA REGION). It occurs in weathered Cambrian sedimentary rocks close to the unconformity with underlying Proterozoic units.

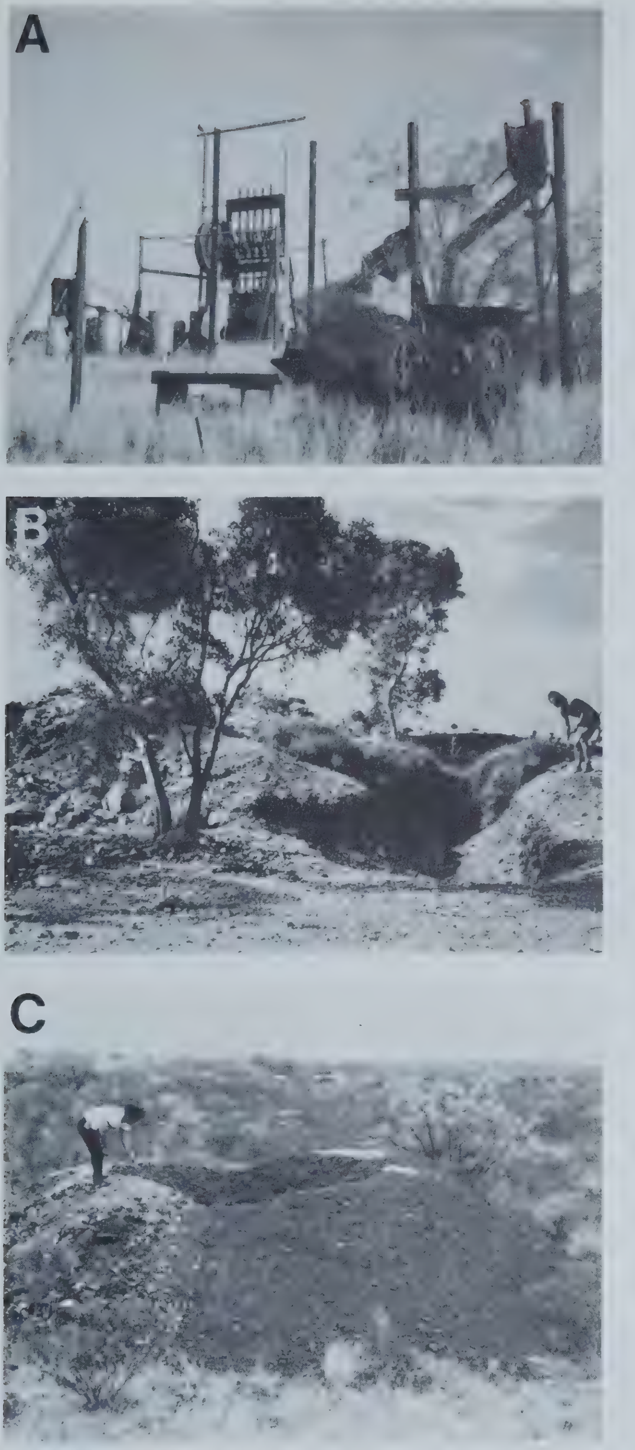


Fig. 86. Gold workings: (A) Kurinelli battery, 1981, near the Dempseys Choice mine (HATCHES CREEK REGION, GR NT040207) — (M2697/22A). (B) the open cut at the Great Davenport mine, 1981 (KURUNDI REGION, GR MT973056) — (M2473/17). (C) Shaft and dump at the Crystal mine, 1982 (HATCHES CREEK REGION, GR NS219953) — (M2567/11)

ECONOMIC POTENTIAL

(DHB)

Although regarded as a tungsten-gold metallogenic province, the Davenport province cannot be considered as being highly prospective for either these or other metals.

The Hatches Creek and Wauchope tungsten fields may become economic if a substantial increase in metal prices is combined with more efficient mining methods and metallurgical processes. Inferred reserves at Hatches Creek, according to Ryan (1961), are about 1000 t tungsten concentrates, but considerably less reserves appear to be present at Wauchope (Sullivan, 1952). None of the known tungsten deposits in the province appear to be large enough to interest a major mining company. As the region has been extensively prospected over many years, there seems to be little likelihood of any significant surface tungsten deposits of quartz-vein type being discovered. Some vein-type deposits of tungsten, and perhaps also tin, may be present at depth associated with granites intruding the Hatches Creek Group, but the possibilities of such deposits proving economic are rated low. As discussed by Hoatson & Cruikshank (1985), the chances of finding skarn-type tungsten deposits are slight, because of the general paucity of carbonates in the Hatches Creek Group and apparent absence of suitable granite, but there may be some potential for stratiform or exhalative scheelite deposits (although these are typically associated with deep-water sediments and volcanics which have been metamorphosed to amphibolite facies, rather than with shallow-water greenschist facies rocks like those of the Hatches Creek Group).

The gold deposits which have been found in the region are small auriferous quartz veins. More deposits of this type may be discovered, but because of their small size and overall low grades, they are not attractive targets for exploration companies. There may be more potential in the region for epithermal-type gold deposits associated with altered felsic volcanics within the Hatches Creek Group.

The Warramunga Group in the north of the Davenport province has some potential for Cu–Au–Bi deposits of Tennant Creek-type. However, no deposits have been found here in spite of considerable exploration company activity since 1970 (Wyche & others, 1987; Wyche, in prep.).

The most prospective unit in the Hatches Creek Group for base metals is considered to be the Frew River Formation (Fig. 87). This formation is thought to have been deposited in very shallow-marine or lacustrine environments, like rocks of similar lithology and possibly age associated with the McArthur River Pb–Zn deposits. Exposures of the Frew River Formation are commonly strongly iron-stained, possibly reflecting the former presence of iron-bearing sulphide minerals.

Some exploration for diamonds has been carried out in the north of the province using stream sediment sampling, but no diamonds or indications for the presence of kimberlitic pipes have been reported (Wyche, in press).

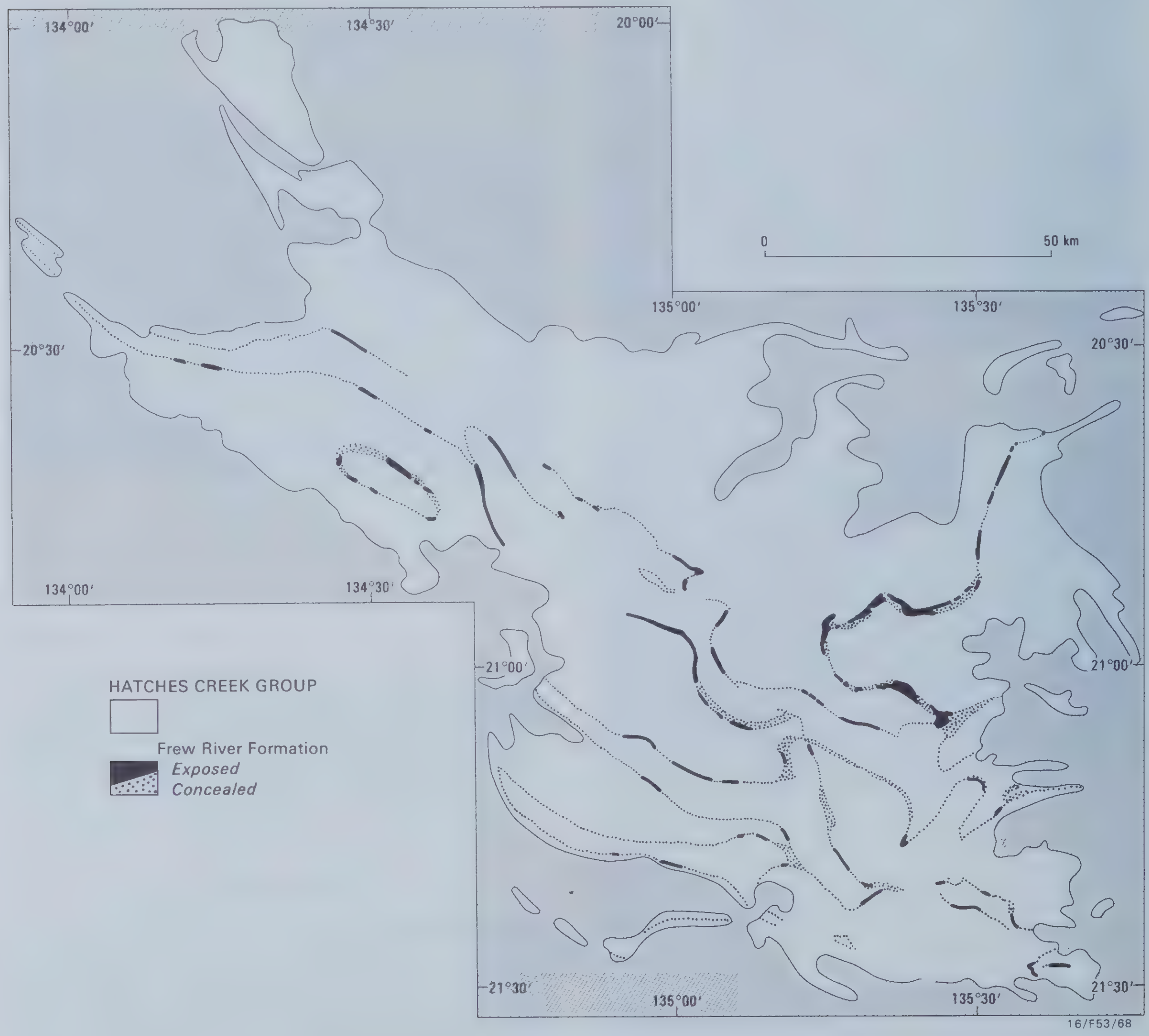


Fig. 87. Distribution of the Frew River Formation, Hatches Creek Group.

SUMMARY OF GEOLOGICAL HISTORY

(DHB)

The earliest recorded event in the Davenport province is the deposition of the sediments and eruption of the volcanics which make up the Warramunga Group, exposed in the north. The sediments included turbidites and chert, and were probably laid down in moderately deep water. Associated felsic volcanism, dated by U-Pb zircon at about 1870 Ma (Black, 1984; Blake & Page, in press), was presumably subaqueous. Some Division 2 rocks of the Arunta Inlier (Stewart & others, 1984) may have been deposited at about the same time to the south but are not exposed in the Davenport province.

After becoming buried and lithified, the Warramunga Group rocks were folded and subjected to low-grade regional metamorphism, and were subsequently intruded by feldspar porphyry. Emplacement of the Hill of Leaders Granite and unnamed granite into the Warramunga Group took place either before or after the deformation, and was followed by the intrusion of some dolerite dykes.

Uplift associated with the deformation and granite emplacement in the north resulted in erosion, leading to exposure of the Warramunga Group, unroofing of granite intrusions, and development of a low-lying terrain of moderate relief.

Regional downwarping, attributed to crustal thinning by extension, resulted in the Davenport province becoming part of an extensive, ensialic depositional basin which may have covered much of central Australia. Ensuing sedimentation in the province was rapid and was accompanied by felsic and mafic volcanism and penecontemporaneous subvolcanic intrusive activity. The sedimentary and igneous rocks formed at this time are represented by the Hatches Creek Group and associated granophyre and mafic intrusions. Chemical evidence indicates that the volcanics of the Hatches Creek Group and the subvolcanic intrusions are comagmatic. Felsic volcanics in the lower part of the group are tentatively dated by U-Pb zircon at 1810-1820 Ma (Blake & Page, in press). Some transfer faults and normal faults were probably active during this period. Sedimentation and the accumulation of volcanic products kept pace with subsidence, so that shallow-marine to fluvial and locally subaerial environments prevailed throughout Hatches Creek Group time.

Most of the clastic sediments of the Hatches Creek Group were probably derived from source areas of Warramunga Group to the north and northwest and Arunta rocks to the south and southwest, but at some stratigraphic levels they contain appreciable amounts of locally derived volcanic detritus. The oldest sediments, those of the Ooradidgee Subgroup, were mainly fluvial (e.g., Kurinelli Sandstone and Taragan Sandstone), but included some deltaic deposits (e.g., Rooneys Formation) and, towards the end of Ooradidgee Subgroup time, shallow-marine sands (in the Treasure Volcanics). Penecontemporaneous volcanism, represented by the mostly felsic Epenarra Volcanics, Treasure Volcanics and Mia Mia Volcanics and the mostly mafic Edmirringee Volcanics, together with the emplacement of hypabyssal intrusions, was largely restricted to the northern and central parts of the Davenport province, where several volcanic centres were present. Some of these centres, such as those represented by the Edmirringee Volcanics, but not, apparently, those that gave rise to the Treasure Volcanics, formed large volcanic cones. Sediments interfingered with lava flows and pyroclastic deposits on the flanks of the volcanoes, and buried the volcanoes after they became extinct. At times earthquakes disrupted bedding in unconsolidated sediment (e.g., Warnes Sandstone Member of the Kurinelli Sandstone) and may have caused slumping and the development of prolapsed cross-bedding. Some of the volcanoes that formed the Epenarra Volcanics seem to have remained active throughout Ooradidgee Subgroup time, but others, such as those represented by the Treasure Volcanics, had much shorter periods of activity.

Fluvial and shallow-marine sedimentation continued during the deposition of the Wauchope Subgroup, which commenced with a thick quartz-rich and partly pebbly sand, represented by the Unimbra Sandstone, being laid down over the entire province. This sand overlapped in the north onto parts of the Warramunga Group that had not been covered by the Ooradidgee Subgroup. It was succeeded by quartzose to volcaniclastic sediments of the Yeeradgi Sandstone and, in the central and southern parts of the province, by felsic lavas and pyroclastics (Arabulja Volcanics and Newlands Volcanics). Again, several volcanic centres were active at about the same time, and a number of high-level sills were emplaced. The upper part of the Yeeradgi Sandstone was locally folded and eroded (in KURUNDI REGION), possibly because of large-scale slumping. When the felsic volcanism ceased, the province was covered by another thick quartz-rich sand blanket, now the Coulters Sandstone. Minor local mafic volcanism accompanied this sedimentation.

The Coulters sand, a shallow-marine deposit, was succeeded by fine-grained clastic sediments and carbonates of the Frew River Formation, a shallowing-upwards sequence. The carbonates included some stromatolitic bioherms, and were laid down in intertidal to supratidal environments.

A period of basaltic and minor trachytic volcanism followed, during which lava flows (Kudinga Basalt) spread out onto a broad fluvial plain or shallow-marine shelf underlain by the Frew River Formation. Feldspathic sands were deposited during intervals between eruptions early in Kudinga Basalt time. Rare possible pillow lava in KURUNDI REGION indicates that although most of the Kudinga volcanism was probably subaerial, some may have been subaqueous.

At the end of the basaltic volcanism, a third extensive thick blanket of quartz-rich sand was deposited, partly on intertidal flats, during a marine transgression. This sand forms the Errolola Sandstone, the basal formation of the Hanlon Subgroup. Shallow-marine and possibly also fluvial and deltaic sedimentation followed, with the deposition of sands, silts and clays of the Alinjabon Sandstone, accompanied by minor mafic volcanism—the youngest volcanism recorded in the province. Water depth may have increased when fine-grained sediments of the overlying Lennee Creek Formation were laid down. Shallow-marine and partly intertidal conditions probably prevailed during deposition of the succeeding Canulgerra Sandstone and, in the easternmost part of the province, Vaddingilla Formation and Yaddanilla Sandstone, the youngest exposed units of the Hatches Creek Group.

Isopach maps show that during the deposition of the Wauchope and Hanlon Subgroups the central part of the Davenport province received a much thinner cover of sediment than the eastern and western parts, indicating that it subsided more slowly. They also show that the Unimbra Sandstone at the base of the Wauchope Subgroup thins over the volcanic centres of the Ooradidgee Subgroup, indicating that these centres were relative highs at the time.

Some time after deposition, the Hatches Creek Group was deformed and regionally metamorphosed to mainly greenschist facies. Some syndepositional faults may have been reactivated as reverse faults and thrusts during the deformation, which involved two main phases of folding, both concentric in style. Northwest-trending folds formed during the first phase were refolded in places by northeast-trending folds. The combination of reverse faulting, thrusting, and concentric folding is suggestive of gravity sliding thin-skinned tectonics. However, no regional decollement zone has been identified either within or below the Hatches Creek Group.

The gold mineralisation in the Davenport province may be related to the tectonism, as during regional metamorphism gold could have been scavenged by fluids permeating the Ooradidgee Subgroup and mafic sills, and deposited in tension cracks, now represented by quartz veins.

The Elkedra Granite, Devils Marbles Granite, and some bodies of unnamed granite were emplaced as steep-sided plutons into the Hatches Creek Group probably at around 1640–1660 Ma, after the main deformation. Lamprophyre dykes cutting the Hill of Leaders Granite in the Mosquito Creek tungsten field may have been intruded a little earlier, at around 1670 Ma.

The mineralisation in the Hatches Creek and Wauchope tungsten fields, and most of the tungsten mineralisation elsewhere in the Davenport province, may be attributed to late-stage hydrothermal solutions emanating from post-tectonic granites. The mineralisation in the Mosquito Creek tungsten field is possibly of similar age and origin, but may be older, perhaps related to lamprophyre dykes or to the host Hill of Leaders Granite.

The presence of some faults cutting the Elkedra Granite and other younger granites indicates that minor faulting probably took place after 1640 Ma.

As a result of the deformation and granite intrusion, the province was elevated well above sea level and became subjected to subaerial erosion. It may have been land for the remainder of the Proterozoic, first being worn down to a peneplain, represented by the present day Ashburton Surface, and later, after further relative uplift and resulting rejuvenation, being dissected to form a landscape similar to that at present, with flat-topped ridges of sandstone separated by valleys cut into less-resistant rocks.

During the Early and early Middle Cambrian, a marine transgression resulted in shallow-marine sediments of the Georgina Basin sequence being deposited unconformably on Precambrian rocks around the margins of the Davenport province. At the same time fluvial sediments partly filled valleys in the central part of the province, which remained above sea level. This central part has probably been a land area throughout the Phanerozoic (Stewart & others, 1986).

Possibly during the Devonian, fluvial sand and gravel were deposited to the southwest and northwest of the province, in the Georgina and Wiso Basins, respectively. Similar sediments of possibly Mesozoic age later covered low-lying parts of the province to the east. Weathering and erosion, with some fluvial and aeolian deposition, prevailed during the Cainozoic, as in other parts of central Australia.

Since the emplacement of granite plutons 1640–1660 Ma ago, the Davenport province has been a tectonically stable part of the north Australian craton.

REFERENCES

A.G.G.S.N.A., 1941—Report for period ended 31st December, 1940. *Aerial, Geological and Geophysical Survey of Northern Australia.*

Allen, J. R. L., 1963—The classification of cross-stratified units with notes on their origin. *Sedimentology*, 2, 93-114.

Allen, J. R. L., 1982—SEDIMENTARY STRUCTURES. THEIR CHARACTER AND PHYSICAL BASIS. *Elsevier, Amsterdam. Developments in Sedimentology*, 30, volume 1.

Allen, J. R. L., & Banks, N. L., 1972—An interpretation and analysis of recumbent-folded deformed cross-bedding. *Sedimentology*, 19, 256-283.

Bally, A. W., 1981—Atlantic-type margins. *In* Geology of passive continental margins. *Continuing Education Course Note Series, American Association of Petroleum Geologists*, 19, 1-48.

Bates, R. L., & Jackson, J. A. (Editors), 1980—GLOSSARY OF GEOLOGY (2nd Edition). *American Geological Institute, Falls Church, Virginia.*

Bell, A. D. M., 1953—Preliminary report on the Mosquito Creek tungsten field. *Bureau of Mineral Resources, Australia, Record* 1953/18.

Black, L. P., 1977—A Rb-Sr geochronological study in the Proterozoic Tennant Creek Block, central Australia. *BMR Journal of Australian Geology & Geophysics*, 2, 111-122.

Black, L. P., 1984—U-Pb zircon ages and a revised chronology for the Tennant Creek Inlier, Northern Territory. *Australian Journal of Earth Sciences*, 31, 123-131.

Blake, D. H., 1978—The Proterozoic and Palaeozoic rocks of The Granites-Tanami region, Western Australia and Northern Territory, and interregional correlations. *BMR Journal of Australian Geology & Geophysics*, 3, 35-42.

Blake, D. H., 1984—Stratigraphic correlations in the Tennant Creek region, central Australia: Warramunga Group, Tomkinson Creek beds, Hatches Creek Group, and Rising Sun Conglomerate. *BMR Journal of Australian Geology & Geophysics*, 9, 41-47.

Blake, D. H., 1987—Geology of the Proterozoic Mount Isa Inlier and environs, Queensland and Northern Territory. *Bureau of Mineral Resources, Australia, Bulletin* 225.

Blake, D. H., & Horsfall, C. L., 1984—Geology of the Elkedra region 1:100 000 map sheet, Northern Territory. *Bureau of Mineral Resources, Australia, Record* 1984/18.

Blake, D. H., & Horsfall, C. L., 1987—Elkedra region, Northern Territory. *Bureau of Mineral Resources, Australia, 1:100 000 Geological Map Commentary.*

Blake, D. H., & Page, R. W., in press—The Proterozoic Davenport province, central Australia: regional geology and geochronology. *Precambrian Research.*

Blake, D. H., & Wyche, S., 1983—Geology of the Hatches Creek region 1:100 000 map sheet, Northern Territory. *Bureau of Mineral Resources, Australia, Record* 1983/18.

Blake, D. H., Hodgson, I. M., & Muhling, P. C., 1979—Geology of The Granites-Tanami region, Northern Territory and Western Australia. *Bureau of Mineral Resources, Australia, Bulletin* 197.

Blake, D. H., Stewart, A. J., Sweet, I. P., & Wyche, S., 1984a—Definitions of newly named and revised Precambrian rock units in the Davenport and Murchison Ranges of central Australia (Northern Territory). *Bureau of Mineral Resources, Australia, Report* 257.

Blake, D. H., Bultitude, R. J., Donchak, P. J. T., Wyborn, L. A. I., & Hone, I. G., 1984b—Geology of the Duchess-Urandangi region, Mount Isa Inlier, Queensland. *Bureau of Mineral Resources, Australia, Bulletin* 219.

Blake, D. H., Wyche, S., & Hone, I. G., 1986a—Hatches Creek region, Northern Territory. *Bureau of Mineral Resources, Australia, 1:100 000 Geological Map Commentary.*

Blake, D. H., Stewart, A. J., & Sweet, I. P., 1986b—The Proterozoic Hatches Creek Group, an ensialic sandstone-bimodal volcanic association in central Australia. *Transactions of the Geological Society of South Africa*, 89, 243-251.

Bourgeois, J., 1980—A transgressive shelf sequence exhibiting hummocky stratification: the Cape Sebastian Sandstone (Upper Cretaceous), southwestern Oregon. *Journal of Sedimentary Petrology*, 50, 681-702.

Brown, H. Y. L., 1895—Government geologist's report on explorations in the Northern Territory. *South Australia Parliamentary Paper* 1895/82.

Brown, H. Y. L., 1896—Report on Northern Territory explorations. *South Australia Parliamentary Paper* 1896/27.

Brown, H. Y. L., 1903—Report on country recently examined in the Davenport and Murchison Ranges. *South Australia Parliamentary Paper* 1903/27.

Bultitude, R. J., & Wyborn, L. A. I., 1982—Distribution and geochemistry of volcanic rocks in the Duchess-Urandangi region, Queensland. *BMR Journal of Australian Geology & Geophysics*, 7, 99-112.

Coleman, J. M., & Wright, L. D., 1975—Modern river deltas: variability of processes and sand bodies. *In* Broussard, M. L. (Editor)—DELTAS, MODELS FOR EXPLORATION. *Houston Geological Society, Houston*, 99-149.

Compston, W., & Arriens, P. A., 1968—The Precambrian geochronology of Australia. *Canadian Journal of Earth Sciences*, 5, 561-583.

Cotter, E., 1978—The evolution of fluvial style with special reference to the central Appalachian Paleozoic. *In* Miall, A. D. (Editor)—FLUVIAL SEDIMENTOLOGY. *Canadian Society of Petroleum Geologists, Memoir* 5, 361-384.

Cox, K. G., 1980—A model for flood basalt volcanism. *Journal of Petrology*, 21, 629-650.

Crohn, P. W., 1976—Tennant Creek-Davenport Proterozoic basins—regional geology and mineralisation. *In* Knight, C. L. (Editor)—ECONOMIC GEOLOGY OF AUSTRALIA AND PAPUA NEW GUINEA. 1. METALS. *The Australasian Institute of Mining and Metallurgy, Monograph* 5, 421-424.

Davidson, A. A., 1905—Journal of explorations in central Australia, 1898-1900. *South Australia Parliamentary Paper* 1905/27.

Dodson, R. G., & Gardener, J. E. F., 1978—Tennant Creek, Northern Territory—1:250 000 Geological Series. *Bureau of Mineral Resources, Australia, Explanatory Notes* SE/53-14.

Dott, R. H. Jr, 1983—The Proterozoic red quartzite enigma in the north-central United States: resolved by plate collision? *Geological Society of America, Memoir* 160, 129-141.

Etheridge, M. A., 1986—Reactivation of extensional fault systems. *Philosophical Transactions of the Royal Society, Series A*, 317, 179-194.

Etheridge, M. A., Branson, J. C., Falvey, D. A., Lockwood, K. L., Stuart-Smith, P. G., & Scherl, A. S., 1984—Basin-forming structures and their relevance to hydrocarbon exploration in Bass Basin, southeastern Australia. *BMR Journal of Australian Geology & Geophysics*, 9, 197-206.

Finlayson, D. M., 1982—Seismic crustal structure of the Proterozoic north Australian craton between Tennant Creek and Mount Isa. *Journal of Geophysical Research*, 87, 10560-10578.

Gibbs, A. D., 1984—Structural evolution of extensional basin margins. *Journal of the Geological Society, London*, 141, 609-620.

Harms, J. C., Southard, J. B., & Walker, R. G., 1982—Structures and sequences in clastic rocks. *Society of Economic Paleontologists and Mineralogists, Short Course Notes*, 9.

Hays, J., 1967—Surfaces and laterites in the N.T. *In* Jennings, J. N., & Mabbutt, J. A. (Editors)—LANDFORM STUDIES FROM AUSTRALIA AND NEW GUINEA. *Australian National University Press, Canberra, 182*-210.

Heckel, P. H., 1972—Recognition of ancient shallow marine environments. *In* Rigby, J. K., & Hamblin, W. K. (Editors)—RECOGNITION OF ANCIENT SEDIMENTARY ENVIRONMENTS. *Society of Economic Paleontologists and Mineralogists, Special Publication*, 16, 226-286.

Heward, A. P., 1978—Alluvial fan sequence and megasequence models: with examples from Westphalian D—Stephanian B coalfields, northern Spain. *In* Miall, A. D. (Editor)—FLUVIAL SEDIMENTOLOGY. *Canadian Society of Petroleum Geologists, Memoir* 5, 669-702.

Hoatson, D. M., & Cruikshank, B. I., 1985—A stream sediment geochemical orientation survey of the Davenport province, Northern Territory. *Bureau of Mineral Resources, Australia, Record* 1985/44.

Hone, I. G., 1983—Gravity, magnetic, and radiometric characteristics of the Davenport Geosyncline, Northern Territory. Abstracts—Twelfth BMR Symposium, 17-18 May 1983, Canberra. *BMR Journal of Australian Geology & Geophysics*, 8, 170.

Hone, I. G., Shaw, R. D., Carberry, V. P., & Reith, H. G., in preparation—Physical property measurements on rock samples from the Davenport region, N.T. *Bureau of Mineral Resources, Australia, Report.*

Hossfeld, P. S., 1954—Stratigraphy and structure of the Northern Territory of Australia. *Transactions of the Royal Society of South Australia*, 77, 103-161.

Hughes, T. C., & Hannaker, P., 1978—The determination of carbon and hydrogen in geological materials by thermal decomposition. *Chemical Geology*, 22, 331-339.

Hurley, P. M., Fisher, N. H., Pinson, W. H., & Fairbairn, H. W., 1961—Geochronology of Proterozoic granites in Northern Territory, Australia. Part 1: K-Ar and Rb-Sr age determinations. *Geological Society of America, Bulletin* 72, 653-662.

Ivanac, J. F., 1954—The geology and mineral deposits of the Tennant Creek Goldfield, Northern Territory. *Bureau of Mineral Resources, Australia, Bulletin* 22.

Johnson, H. D., 1978—Shallow siliciclastic seas. *In* Reading, H. G. (Editor)—sedimentary environments and facies. *Blackwell, Oxford*, 207-258.

Joklik, G. F., & Tomich, S. A., 1951—Report on an inspection of the Mosquito Creek, Northern Territory, Wolfram Field. *Bureau of Mineral Resources, Australia, Record* 1951/53.

Jones, N. O., & Quinlan, T., 1962—An outline of the water resources of the Alice Springs area. *In* Perry, R. A., & others—General report on lands of the Alice Springs area, Northern Territory, 1956-57. *CSIRO, Australia, Land Research Series* 6, 150-162.

Kennewell, P. J., & Huleatt, M. B., 1980—Geology of the Wiso Basin, Northern Territory. *Bureau of Mineral Resources, Australia, Bulletin* 205.

Komar, P. D., 1974—Oscillatory ripple marks and the evaluation of ancient wave conditions and environments. *Journal of Sedimentary Petrology*, 44, 169-180.

Langron, W. J., 1957—Carborne radiometric surveys in the Davenport Range area, N.T., 1956. *Bureau of Mineral Resources, Australia, Record* 1957/58.

Large, R. R., 1975—Zonation of hydrothermal minerals at the Juno mine, Tennant Creek goldfield, central Australia. *Economic Geology*, 70, 1387-1413.

Livingstone, D. F., 1957—Airborne scintillograph survey in the Mosquito Creek region, Northern Territory, 1956. *Bureau of Mineral Resources, Australia, Record* 1957/80.

Long, D. G. F., 1978—Proterozoic stream deposits: some problems of recognition and interpretation of ancient sandy fluvial systems. *In* Miall, A. D. (Editor)—fluvial sedimentology. *Canadian Society of Petroleum Geologists, Memoir* 5, 313-341.

Lord, J. H., 1955—Report on an inspection of a uranium prospect near Mosquito Creek, Northern Territory. *Bureau of Mineral Resources, Australia, Record* 1955/62.

Lord, J. H., 1956—Report on an inspection of the uranium prospect near Mosquito Creek, Northern Territory. *Bureau of Mineral Resources, Australia, Record* 1956/114.

Mabbutt, J. A., 1962—Geomorphology of the Alice Springs area. *In* Perry, R. A., & others—General report on lands of the Alice Springs area, Northern Territory, 1956-57. *CSIRO, Australia, Land Research Series* 6, 163-184.

McCabe, P. J., 1978—Bedforms from abandoned fluvial channels, Carboniferous, Maritime Provinces. *In* Miall, A. D. (Editor)—fluvial sedimentology. *Canadian Society of Petroleum Geologists Memoir* 5, 854.

McCabe, P. J., & Jones, C. M., 1977—Formation of reactivation surfaces within superimposed deltas and bedforms. *Journal of Sedimentary Petrology*, 47, 707-715.

Miall, A. D., 1978—Lithofacies types and vertical profile models in braided river deposits: a summary. *In* Miall, A. D. (Editor)—fluvial sedimentology. *Canadian Society of Petroleum Geologist Memoir* 5, 597-604.

Moore, P. S., & Hocking, R. M., 1983—Significance of hummocky cross-stratification in the Permian of the Carnarvon Basin, Western Australia. *Journal of the Geological Society of Australia*, 30, 323-332.

Mulder, J. M., 1960—Davenport Range airborne radiometric follow-up survey, N.T. 1957. *Bureau of Mineral Resources, Australia, Record* 1960/106.

Murray, W. R., 1907—Record of prospecting operations in country south-west from Barrow's Creek, and the Davenport Ranges—1906. *South Australia Parliamentary Paper* 1907/9.

Norrish, K., & Chappell, B., 1977—X-ray fluorescence spectrography. *In* Zussman, J. (Editor)—physical methods in determinative mineralogy. *Academic Press, London*, 161-214.

Norrish, K., & Hutton, J. T., 1969—An accurate X-ray spectrographic method for the analysis of a wide range of geological samples. *Geochimica et Cosmochimica Acta*, 33, 431-453.

Oliver, T. G., 1916—Report of inspection on Hatches Creek wolfram mines. *Bulletins of the Northern Territory of Australia*, 21.

Perry, R. A., & Lazarides, M., 1962—Vegetation of the Alice Springs area. *In* Perry, R. A., & others—General report on lands of the Alice Springs area, Northern Territory, 1956-57. *CSIRO, Australia, Land Research Series* 6, 208-239.

Pettijohn, F. J., Potter, P. E., & Siever, R., 1973—sand and sandstone. *Springer-Verlag, Berlin*.

Plumb, K. A., 1979a—The tectonic evolution of Australia. *Earth-Science Reviews*, 14, 205-249.

Plumb, K. A., 1979b—Structure and tectonic style of the Precambrian shields and platforms of northern Australia. *Tectonophysics*, 58, 291-325.

Plumb, K. A., Derrick, G. M., Needham, R. S., & Shaw, R. D., 1981—The Proterozoic of northern Australia. *In* Hunter, D. S. (Editor)—Precambrian of the southern hemisphere. *Developments in Precambrian Geology*, 2, 205-307.

Reineck, H.-E., & Singh, I. B., 1980—depositional sedimentary environments. *Springer-Verlag, Berlin*, 2nd Edition.

Roarty, M., 1977—The Kurundi goldfield. *Northern Territory Geological Survey Report* GS77/13 (unpublished).

Rust, B. R., 1978—Depositional models for braided alluvium. *In* Miall, A. D. (Editor)—fluvial sedimentology. *Canadian Society of Petroleum Geologists, Memoir* 5, 605-625.

Ryan, G. R., 1961—The geology and mineral resources of the Hatches Creek wolfram field, Northern Territory. *Bureau of Mineral Resources, Australia, Bulletin* 6.

Slatyer, R. O., 1962—Climate of the Alice Springs area. *In* Perry, R. A., & others—General report on lands of the Alice Springs area, Northern Territory, 1956-57. *CSIRO, Australia, Land Research Series* 6, 109-128.

Smith, K. G., 1964—Frew River, N.T.—1:250 000 Geological Series. *Bureau of Mineral Resources, Australia, Explanatory Notes* SF/53-3.

Smith, K. G., 1970—Bonney Well, Northern Territory—1:250 000 Geological Series. *Bureau of Mineral Resources, Australia, Explanatory Notes* SF/53-2.

Smith, K. G., & Milligan, E. N., 1964—Barrow Creek, N.T.—1:250 000 Geological Series. *Bureau of Mineral Resources, Australia, Explanatory Notes* SF/53-6.

Smith, K. G., & Milligan, E. N., 1966—Elkedra, N.T.—1:250 000 Geological Series. *Bureau of Mineral Resources, Australia, Explanatory Notes* SF/53-7.

Smith, K. G., Stewart, J. R., & Smith, J. W., 1961—The regional geology of the Davenport and Murchison Ranges, Northern Territory. *Bureau of Mineral Resources, Australia, Report* 58.

Stewart, A. J., in press—Fault reactivation and superimposed folding in a Proterozoic sandstone-volcanic sequence, Davenport province, central Australia. *Journal of Structural Geology.*

Stewart, A. J., & Blake, D. H., 1984—Geology of the Kurundi region 1:100 000 map sheet, Davenport province, Northern Territory. *Bureau of Mineral Resources, Australia, Record* 1984/17.

Stewart, A. J., & Blake, D. H., 1986—Kurundi region, Northern Territory. *Bureau of Mineral Resources, Australia, 1:100 000 Geological Map Commentary.*

Stewart, A. J., Shaw, R. D., & Black, L. P., 1984—The Arunta Inlier: a complex ensialic mobile belt in central Australia. Part 1: stratigraphy, correlations and origin. *Australian Journal of Earth Sciences*, 31, 445-455.

Stewart, A. J., Blake, D. H., & Ollier, C. D., 1986—Cambrian river terraces and ridgetops in central Australia: oldest persisting landforms? *Science*, 233, 758-761.

Stidolph, P. A., Bagas, L., Donnellan, N., Walley, A. M., Morris, D., & Simons, B., in preparation—Elkedra, Northern Territory—1:250 000 Geological Series, 2nd Edition. *Northern Territory Department of Mines and Energy, Explanatory Notes* SF/53-7.

Streckeisen, A. L., & others, 1973—Plutonic rocks. Classification and nomenclature recommended by the IUGS Subcommission on the Systematics of Igneous Rocks. *Geotimes*, 18(10), 26-30.

Sullivan, C. J., 1951—Hatches Creek wolfram field. *Bureau of Mineral Resources, Australia, Record* 1951/35.

Sullivan, C. J., 1952—Wauchope wolfram field. *Bureau of Mineral Resources, Australia, Bulletin* 4.

Sullivan, C. J., 1953a—Hatches Creek wolfram field, Northern Territory. *In* Edwards, A. B. (Editor)—Geology of Australian ore deposits. *5th Empire Mining and Metallurgical Congress Publications*, 1, 322-326.

Sullivan, C. J., 1953b—Wauchope wolfram field. *In* Edwards, A. B. (Editor)—Geology of Australian ore deposits. *5th Empire Mining and Metallurgical Congress Publications*, 1, 327-329.

Tucker, D. H., Wyatt, B. W., Druce, E. C., Mathur, S. P., & Harrison, P. L., 1979—The upper crustal geology of the Georgina Basin region. *BMR Journal of Australian Geology & Geophysics*, 4, 209-226.

Twidale, C. R., 1980—The Devil's Marbles, Central Australia. *Transactions of the Royal Society of South Australia*, 104, 41-49.

Walker, R. G., & Cant, D. J., 1979—Sandy fluvial systems. *In* Walker, R. G. (Editor)—FACIES MODELS. *Geoscience Canada, Reprint Series*, 1, 23-32.

Wyborn, L. A. I., & Page, R. W., 1983—The Proterozoic Kalkadoon and Ewen Batholiths, Mount Isa Inlier, Queensland: source, chemistry, age, and metamorphism. *BMR Journal of Australian Geology & Geophysics*, 8, 51-69.

Wyche, S., in press—Bonney Well, Northern Territory, 1:250 000 Geological Series, 2nd Edition. *Northern Territory Department of Mines and Energy, Explanatory Notes* SF53/2.

Wyche, S., & Blake, D. H., 1984—Geology of the Devils Marbles region 1:100 000 map sheet, Northern Territory. *Bureau of Mineral Resources, Australia, Record* 1984/16.

Wyche, S., Blake, D. H., & Simons, B., 1987—Devils Marbles region, Northern Territory. *Bureau of Mineral Resources, Australia, 1:100 000 Geological Map Commentary.*

APPENDIX — CHEMICAL ANALYSES OF IGNEOUS ROCKS

Analytical methods

170 samples of igneous rocks collected in 1981–1984 from the Davenport province have been analysed for major and trace elements. The analyses are listed in the microfiche in back-pocket of this Bulletin. Most of the analyses were carried out in BMR laboratories using X-ray fluorescence (XRFS), chemical, and atomic absorption (AAS) techniques. However, five samples collected in 1981 were analysed for major and trace elements by The Australian Mineral Development Laboratories (AMDEL) in 1982 using inductively coupled plasma-atomic emission spectroscopy (ICP), chemical, XRFS, and AAS methods (codes H3/1, H3/2, H3/3, B1/1, B1/2, C4, C5; Report AC 5748/82); AMDEL also analysed 66 samples for CO_2, H_2O+, and H_2O- (Reports AC 1100/84, AC 2616/84, method code 01) and eight samples for F (Report AC 4451/84, method code 02).

BMR analyses. At BMR, XRFS analyses were carried out using a Philips PW1450 spectrometer and AAS analyses by using Varian AA-6 and AA-975 spectrophotometers.

SiO_2, TiO_2, Al_2O_3, Fe_2O_3 (total), MnO, MgO, CaO, K_2O, P_2O_3 and S were determined by XRFS using fusion discs according to the method of Norrish & Hutton (1969). International rock standards were used for the calibration.

Na_2O was determined by AAS after digestion of the sample in hydrofluoric and perchloric acids. The analyte solution contained controlled amounts of hydrochloric acid and K+, and calibration was against identical solutions prepared from secondary (BMR) rock standards.

FeO was determined by titration with standard potassium dichromate solution, after digestion of the sample in hydrofluoric acid in the absence of air.

CO_2, H_2O+ and H_2O- were determined gravimetrically using the method and apparatus described by Hughes & Hannaker (1978). Samples were dried in an oven at 110°C to determine H_2O-, and then decomposed at 1100°C in O_2 with evolved CO_2 and H_2O trapped and weighed.

As, Bi, Ga, Pb, Rb, Se (none detected), Sr, Th, U, W and Y (Mo target X-ray tube), and Ba, Ce, Cr, La, Mo, Nb, Nd, Sc, Sn, Ti, V and Zr (Au target tube) were determined by XRFS using pressed powder pellets and the method of Norrish & Chappell (1977) to convert raw counts into element concentrations. Calibration was by synthetic standards (except Rb by NBS-70A and Sr by AGV-1), and was verified against international and secondary rock standards. Mass absorption corrections were made using the Compton scatter method for wavelengths 1.94 A and by calculation from major element data for wavelengths 1.94 A.

Be, Co, Cr, Cu, Li, Ni and Zn were determined by AAS after digestion of the sample in hydrofluoric and perchloric acids, and with direct calibration against standard solutions (except Li). Non-atomic absorption corrections were made for low concentrations of Co, Ni and Zn. Li was determined by the method of standard additions.

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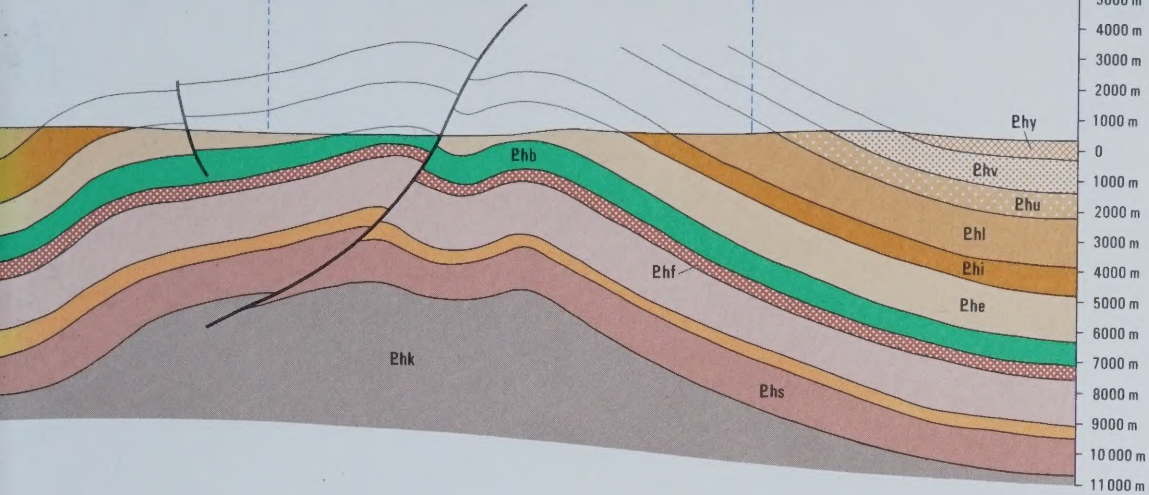

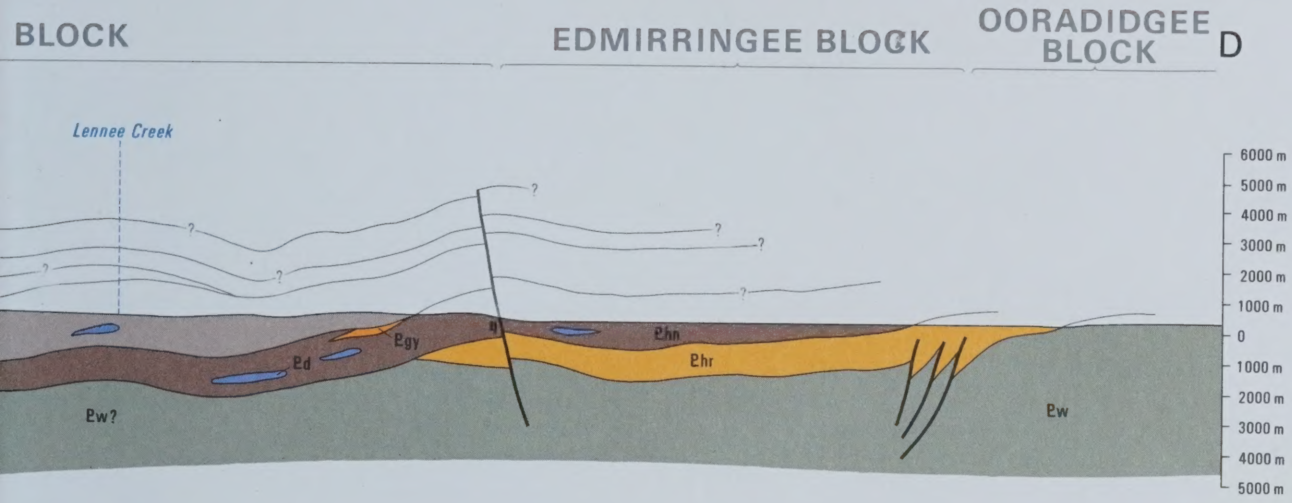

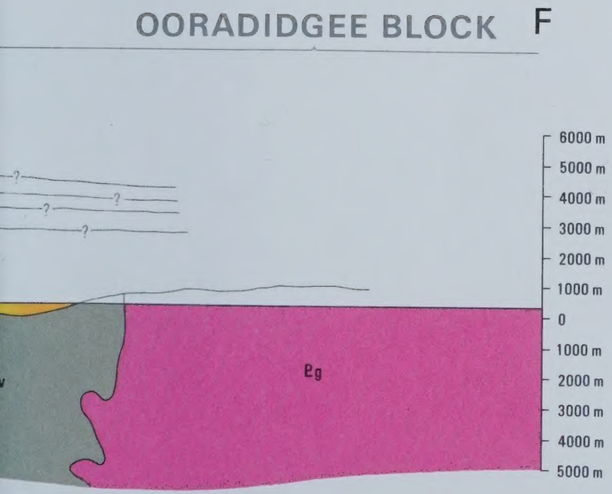

GEOLOGY OF THE

DAVENPORT PROVINCE

FIRST EDITION 1988

GEOLOGY OF THE
DAVENPORT PROVINCE

By D. H. Blake, A. J. Stewart & S. Wyche

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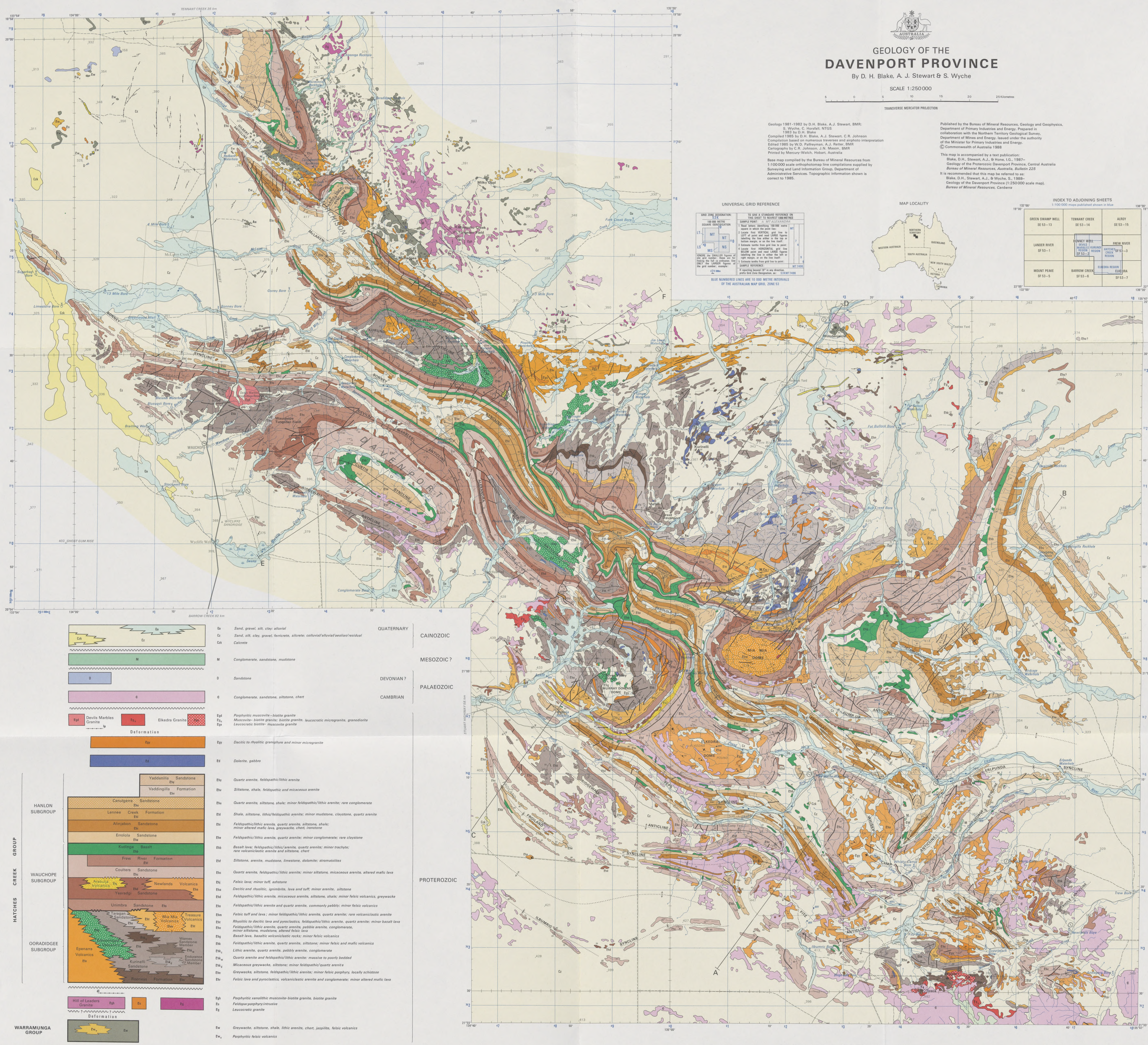

Geology 1981-1982 by D.H. Blake, A.J. Stewart, BMR;
S. Wyche, C. Horsfall, NTGS
1983 by D.H. Blake
Compiled 1985 by D.H. Blake, A.J. Stewart, C.R. Johnson
Compilation based on numerous traverses and airphoto interpretation
Edited 1985 by W.D. Palfreyman, A.J. Retter, BMR
Cartography by C.R. Johnson, J.N. Mason, BMR
Printed by Mercury-Walch, Hobart, Australia

Base map compiled by the Bureau of Mineral Resources from 1:100 000 scale orthophotomap line compilations supplied by Surveying and Land Information Group, Department of Administrative Services. Topographic information shown is correct to 1985.

Published by the Bureau of Mineral Resources, Geology and Geophysics, Department of Primary Industries and Energy. Prepared in collaboration with the Northern Territory Geological Survey, Department of Mines and Energy. Issued under the authority of the Minister for Primary Industries and Energy.
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This map is accompanied by a text publication:
Blake, D.H., Stewart, A.J., & Hone, I.G., 1987–
Geology of the Proterozoic Davenport Province, Central Australia
Bureau of Mineral Resources, Australia, Bulletin 225
It is recommended that this map be referred to as:
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GREEN SWAMP WELL SE 53–13	TENNANT CREEK SE 53–14	ALROY SE 53–15
LANDER RIVER SF 53–1	BONNEY WELL SF 53–2 DEVILS MARBLES REGION KURUNDI REGION	FREW RIVER SF 53–3 HATCHES CREEK REGION
MOUNT PEAKE SF 53–5	BARROW CREEK SF 53–6	ELKEDRA SF 53–7 ELKEDRA REGION

132°00′ 136°30′ 19°00′ 22°00′

Symbol	Description	Period	Era
Qa	Sand, gravel, silt, clay: alluvial	QUATERNARY	CAINOZOIC
Cz	Sand, silt, clay, gravel, ferricrete, silcrete; colluvial/alluvial/aeolian/residual		
Czk	Calcrete		
M	Conglomerate, sandstone, mudstone		MESOZOIC ?
D	Sandstone	DEVONIAN ?	PALAEOZOIC
Ꞓ	Conglomerate, sandstone, siltstone, chert	CAMBRIAN	
Ꝑgd	Devils Marbles Granite: Porphyritic muscovite–biotite granite		PROTEROZOIC
Ꝑgu	Muscovite- biotite granite; biotite granite, leucocratic microgranite, granodiorite		
Ꝑge	Elkedra Granite: Leucocratic biotite- muscovite granite		
	Deformation		
Ꝑgy	Dacitic to rhyolitic granophyre and minor microgranite		
Ꝑd	Dolerite, gabbro		
Ꝑhy	Yaddanilla Sandstone: Quartz arenite, feldspathic/lithic arenite		
Ꝑhv	Vaddingilla Formation: Siltstone, shale, feldspathic and micaceous arenite		
Ꝑhu	Canulgerra Sandstone (HANLON SUBGROUP): Quartz arenite, siltstone, shale; minor feldspathic/lithic arenite; rare conglomerate		
Ꝑhl	Lennee Creek Formation (HANLON SUBGROUP): Shale, siltstone, lithic/feldspathic arenite; minor mudstone, claystone, quartz arenite		
Ꝑhi	Alinjabon Sandstone (HANLON SUBGROUP): Feldspathic/lithic arenite, quartz arenite, siltstone, shale; minor altered mafic lava, greywacke, chert, ironstone		
Ꝑhe	Errolola Sandstone (HANLON SUBGROUP): Feldspathic/lithic arenite, quartz arenite; minor conglomerate; rare claystone		
Ꝑhb	Kudinga Basalt (WAUCHOPE SUBGROUP): Basalt lava; feldspathic/lithic/arenite, quartz arenite; minor trachyte; rare volcaniclastic arenite and siltstone, chert		
Ꝑhf	Frew River Formation (WAUCHOPE SUBGROUP): Siltstone, arenite, mudstone, limestone, dolomite; stromatolites		
Ꝑhc	Coulters Sandstone (WAUCHOPE SUBGROUP): Quartz arenite, feldspathic/lithic arenite; minor siltstone, micaceous arenite, altered mafic lava		
Ꝑhj	Arabulja Volcanics (WAUCHOPE SUBGROUP): Felsic lava; minor tuff, ashstone		
Ꝑha	Newlands Volcanics (WAUCHOPE SUBGROUP): Dacitic and rhyolitic, ignimbrite, lava and tuff; minor arenite, siltstone		
Ꝑhd	Yeeradgi Sandstone (WAUCHOPE SUBGROUP): Feldspathic/lithic arenite, micaceous arenite, siltstone, shale; minor felsic volcanics, greywacke		
Ꝑhs	Unimbra Sandstone (WAUCHOPE SUBGROUP): Feldspathic/lithic arenite and quartz arenite, commonly pebbly; minor felsic volcanics		
Ꝑhm	Mia Mia Volcanics (OORADIDGEE SUBGROUP): Felsic tuff and lava ; minor feldspathic/lithic arenite, quartz arenite; rare volcaniclastic arenite		
Ꝑht	Treasure Volcanics (OORADIDGEE SUBGROUP): Rhyolitic to dacitic lava and pyroclastics, feldspathic/lithic arenite, quartz arenite; minor basalt lava		
Ꝑho	Taragan Sandstone (OORADIDGEE SUBGROUP): Feldspathic/lithic arenite, quartz arenite, pebble arenite, conglomerate, minor siltstone, mudstone, altered felsic lava		
Ꝑhg	Edmirringee Volcanics (OORADIDGEE SUBGROUP): Basalt lava, basaltic volcaniclastic rocks; minor felsic volcanics		
Ꝑhk	Kurinelli Sandstone (OORADIDGEE SUBGROUP): Feldspathic/lithic arenite, quartz arenite, siltstone; minor felsic and mafic volcanics		
Ꝑhkc	Lithic arenite, quartz arenite, pebbly arenite, conglomerate		
Ꝑhkw	Warnes Sandstone Member: Quartz arenite and feldspathic/lithic arenite: massive to poorly bedded		
Ꝑhkd	Endurance Sandstone Member: Micaceous greywacke, siltstone; minor feldspathic/quartz arenite		
Ꝑhn	Rooneys Formation (OORADIDGEE SUBGROUP): Greywacke, siltstone, feldspathic/lithic arenite; minor felsic porphyry, locally schistose		
Ꝑhr	Epenarra Volcanics (OORADIDGEE SUBGROUP): Felsic lava and pyroclastics, volcaniclastic arenite and conglomerate; minor altered mafic lava		
Ꝑgh	Hill of Leaders Granite: Porphyritic xenolithic muscovite-biotite granite, biotite granite		
Ꝑo	Feldspar porphyry:intrusive		
Ꝑg	Leucocratic granite		
	Deformation		
Ꝑw	WARRAMUNGA GROUP: Greywacke, siltstone, shale, lithic arenite, chert, jaspilite, felsic volcanics		
Ꝑwv	Porphyritic felsic volcanics		

HATCHES CREEK GROUP: HANLON SUBGROUP, WAUCHOPE SUBGROUP, OORADIDGEE SUBGROUP

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Unconformity

PROTEROZOIC GEOLOGY AND STRUCTURE

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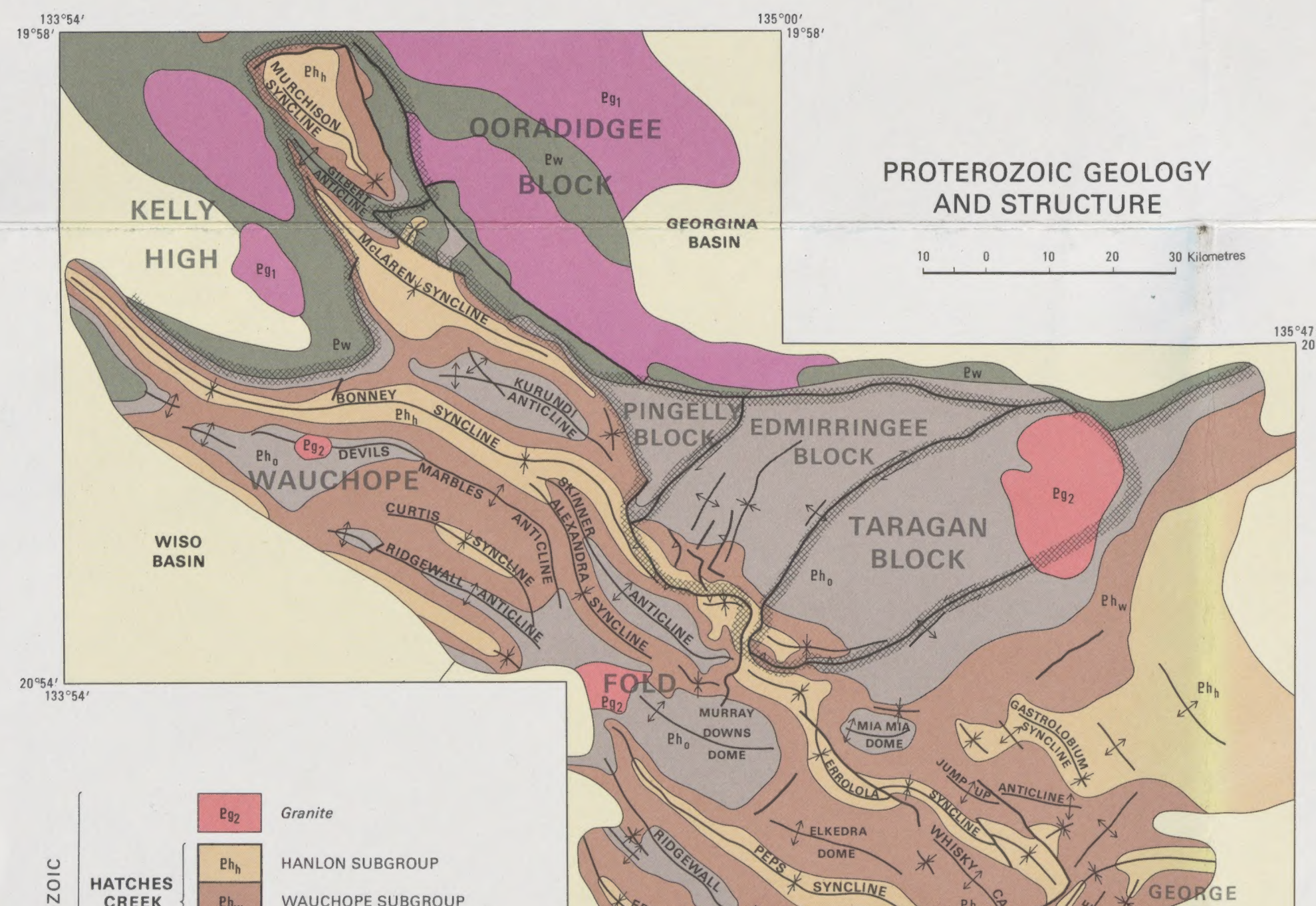
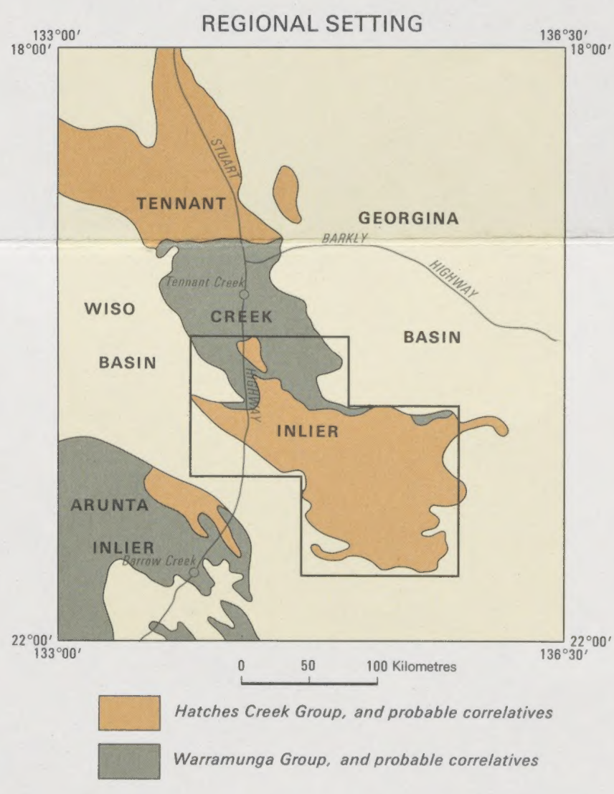


PROTEROZOIC

Ꝑg2	Granite
Ꝑhh	HANLON SUBGROUP (HATCHES CREEK GROUP)
Ꝑhw	WAUCHOPE SUBGROUP (HATCHES CREEK GROUP)
Ꝑho	OORADIDGEE SUBGROUP (HATCHES CREEK GROUP)
Ꝑg1	Granite
Ꝑw	WARRAMUNGA GROUP

REGIONAL SETTING



🟧	Hatches Creek Group, and probable correlatives
⬛	Warramunga Group, and probable correlatives

Symbol	Meaning	Symbol	Meaning
	Geological boundary		Syncline; upright fold showing trend and plunge of axis
	Block boundary (Proterozoic Geology and Structure sketch only)		Syncline; inclined or reclined fold showing axial plane trace and trend and plunge of axis
	Reverse fault (Proterozoic Geology and Structure sketch only)		Overturned anticline
	Fault showing relative horizontal displacement (Proterozoic Geology and Structure sketch only)		Overturned syncline
	Fault		Concealed fold
q	Fault containing: q – quartz		Strike and dip of strata
	Fault zone with crushing		Strike and dip of strata, facing not known
dl, lp	Dyke or vein; dl – dolerite, lp – lamprophyre, unlabelled dykes are quartz		Vertical strata
	Anticline; upright fold showing trend and plunge of axis	+	Horizontal strata
	Anticline; inclined or reclined fold showing axial plane trace and trend and plunge of axis		Strike and dip of overturned strata

Symbol	Meaning
	Trend line (airphoto interpretation)
	Joint pattern (airphoto interpretation)
	Strike and dip of foliation
	Vertical foliation
	Strike and dip of cleavage
	Vertical cleavage
	Strike and dip of platy flow structure
	Fossil locality
⚒	Mine
	Prospect

Ag – Silver, Au – Gold, Cu – Copper, Pb – Lead, Tq – Turquoise, U – Uranium, W – Tungsten

Symbol	Meaning
○	Bore or well
	Bore with windpump
E	Earth dam
T	Water tank
WH	Waterhole
RH	Rockhole
	Swamp
	Highway
	Minor road
	Vehicle track
	Fence
⊖	Landing ground
Kurundi	Homestead
·	Building
▫	Yard
△	Trigonometrical station
.266	Elevation in metres
abd	Abandoned

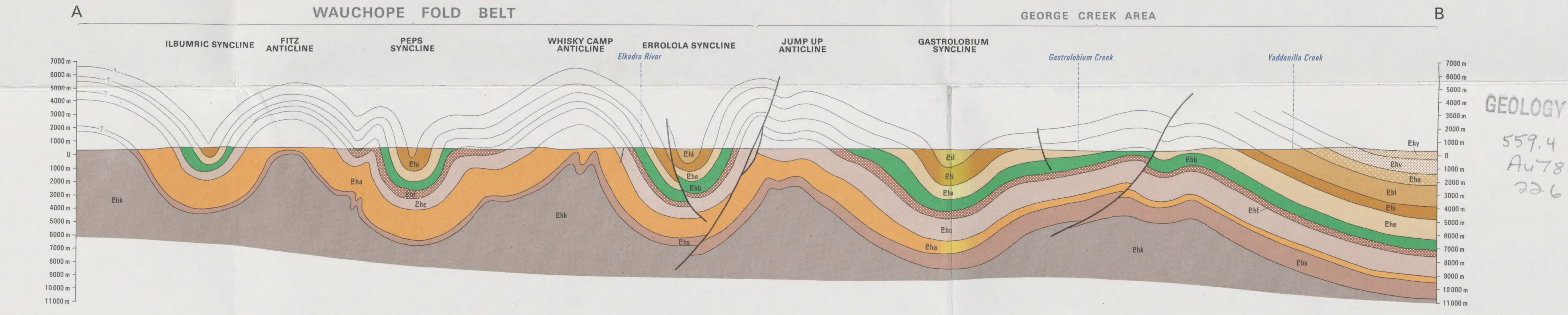
SCHEMATIC SECTIONS

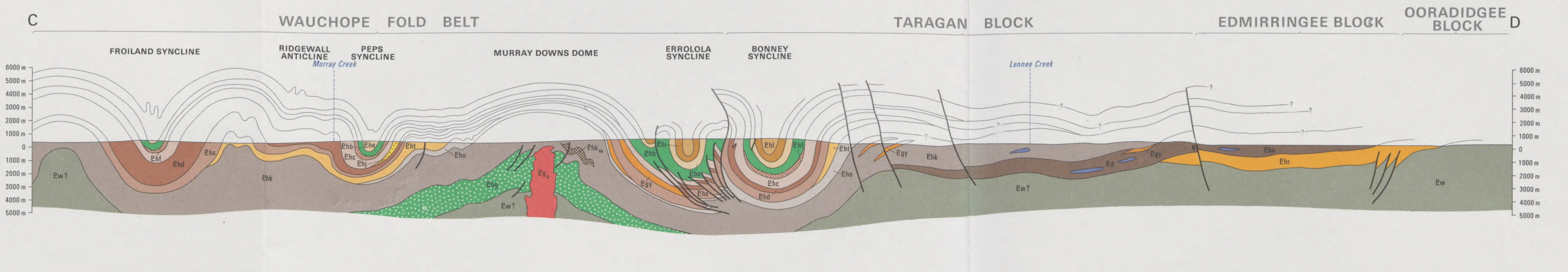
Phanerozoic sediments omitted

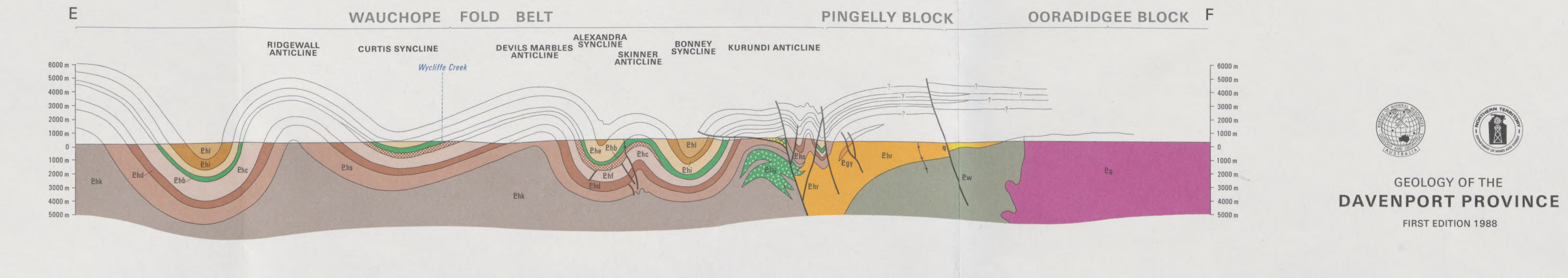
Scale $\frac{V}{H} = 1$

Restorable cross-section based on the following assumptions:

1. *Folding is concentric, therefore bed length is held constant between axial planes of major folds or areas of horizontal bedding*
2. *Bedding-parallel faults are reverse faults; decrease in dip with depth; tend to be bedding-parallel in incompetent rocks, and bedding-oblique in competent rocks*
3. *Reverse faults continue below Hatches Creek Group into basement owing to absence of incompetent rocks at base of Group ("thick-skinned tectonics")*
4. *No diapiric growth of anticlines*
5. *Effects of unknown thickness of overlying sediments ignored*
6. *Information off-section is projected on-section by "down structure" method*
7. *Shortening in hinge zones may be accommodated by imbricate faults, plications, or combinations of both*







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